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SIGNIFICANCE OF TORTUOUS FILLING DEFECTS AT LUMBAR MYELOGRAPHY

STEN CRONQVIST and CARL AXEL THULIN

The non ionic water soluble contrast medium Amipaque has been widely accepted and is being increasingly used in the examination of the subarachnoid space of the entire spinal canal Being water soluble it has the capacity to penetrate narrow spaces permitting demonstration of fine details details rarely or never seen when oily contrast media or oxygen are used Consequently, findings up to now only rarely observed will be met with more frequently

One such finding is the occurrence of defects with a serpentine appearance in the contrast column Several explanations of these defects have been given and the recognition of their nature is important for differential diagnostic reasons

This abnormality is found in conjunction with a marked narrowing a stenosis of the spinal canal Such a stenosis may be developmental and include the entire lumbar canal or may be acquired and then secondary to extensive general or local arthrosis Excessive narrowing has been reported in malformations like achondrodysplasia (DE LANGE 1967 GARDNER cited by SORENSEN & WIRTHLIN 1975) In these cases the tortuous defects may occupy the entire lumbar subarachnoid space from the medullary conus and downwards i e corresponding to the extension of the cauda equina Most frequently however the defects are found in the presence of a marked local narrowing due to a local arthrosis or to a large herniation or protrusion of a disc or to the simultaneous presence of more than one lesion (Fig 1) It has also been observed in cases of extra as well as intradural tumors or malformations (Fig 2) The serpentine appearance is localized in the region immediately cranial to the

From the Department of Diagnostic Radiology Section of Neuroradiology and Department of Neurosurgery University Hospital S-221 85 Lund Sweden Submitted for publication 5 October 19 8

Fig 1

Fig 2

Fig 3

Fig 1 Multiple deformations the lower one due to bony abnormalities the upper to a herniated disc Cranially to the herniation irregular course of multiple nerve roots due to compression and displacement

Fig 2 Intradural neurinoma causing complete block Tortuous filling defects representing displaced nerve roots immediately above the upper tumor pole

Fig 3 Tortuous filling defects caudally to a herniated disc

narrowed space with an extension from one to several centimeters Rarely it may also appear caudal to the obstruction exceptionally it may be restricted only to this area (Fig 3) When multiple narrowings are present the abnormality may be found at more than one level If marked it is evident in a p p a and lateral projections The defect may appear as one single tortuous strand with a diameter of 2 to 3 mm possible to trace in its entire course within the contrast column or confined to both sides of the narrowed region (Fig 4) In the cranial direction it eventually assumes a more regular form taking a straight course and running along the longitudinal axis of the spinal canal More often multiple defects of the same type are found with the individual components still possible to distinguish In other cases the defects are excessive forming a mass with an irregular appearance This may be so marked

Fig. 4 Fig 5 Fig 6

Fig 4 Partial block due to herniated disc in the midline Tortuous filling defects representing elongated nerve roots both below and above the herniation

Fig 5 Herniated disc causing a partial block with only droplets of contrast medium close to the block Irregular defects extending cranially for a long distance

Fig 6 Partial block with two tortuous filling defects representing elongated nerve roots They are visible in their entire course above and below the block as well as at the level of the block

that the contrast medium within the affected region appears only as separate small irregular droplets (Fig 5)

Defects of the kind described may be caused by abnormal or displaced nerve roots or by a vascular abnormality such as an arteriovenous malformation or a venous angioma The possibility of congested or varicose veins must also be considered (TAVERAS & DALTON 1961)

At this radiologic department tortuous filling defects in relation to a local stenosis or narrowing of the spinal canal have frequently been found at lumbar myelography However the impression gained is that the tortuosity may be of two different types One type appears to be due to elongated nerve roots another type to normal but displaced nerve roots The first mentioned abnormality has been referred to as root redundancy (CRESSMAN & PAWL 1968) Only a few such cases have been described

Fifteen have been found in the literature (VERBIEST 1954, HANRAETS 1959, CRISSMAN & PAWL, SCHUT & GROFF 1968, FOX 1969, LOMBARDI 1969, EHNI et coll 1970 GULATI & ROUT 1973, SORENSEN & WIRTHLIN 1975, VARUGHESE 1976 PAU & TURTAS 1976, KONDO et coll 1978) In the textbook on neuroradiology by TAVERAS & WOOD (1964) such a case is illustrated An additional 5 cases have recently been published by one of us (THULIN et coll 1978)

The tortuous course of a nerve root in the spinal canal has in these cases been suggested to be a result of its elongation More than one root may be affected and then form an irregular mass at myelography Whether redundant roots are to be considered a pathologic entity or a normal variation is a matter of discussion In all published cases but one (EHNI et coll) some other types of abnormality of the spinal canal have also been present and all these patients had symptoms and signs of segmental deficit of the cauda equina The exceptional case reported by EHNI et coll had no symptoms from the lumbar region which at myelography, except for the tortuous filling defect, was considered to be completely normal The myelography in this case was performed because of suggested cervical myelo and radiculopathy No operation was performed and the finding was not confirmed This case favours the suggestion that redundancy of nerve roots is a normal variation So does also the observation that a tortuous filling defect sometimes can be traced along its entire course both above and below a local stenosis (Fig 6) Thus the simultaneous occurrence of other abnormalities than tortuosity may be purely accidental (Fig 7) On the other hand, in more than 200 myelographies of the thoracic and of the cervical region in which also the lumbar region was included in the examination no redundant roots were observed

In 5 cases root redundancy was confirmed at operation In 3 cases they were visible after opening the dura In 2 the dura ruptured spontaneously during the operation at the site of the puncture for the pre operative myelography, with the roots suddenly emerging The number of elongated roots varied from one to 5 In all cases the spinal canal was locally narrowed due to laminar thickening a hypertrophic flaval ligament or protrusion or herniation of an intervertebral disc At myelography the local narrowing caused only a partial block in one case and contrast medium appeared below above and at the level of the narrowed space In two cases the block was more marked with medium only above and below while in the 2 remaining cases the block was complete

In the majority of the present cases the tortuous filling defects were more evident with most or all of the nerve roots involved Occasionally one or two of these were more tortuous than the others (Fig 7) In all cases a marked partial block existed which the contrast medium passed with difficulty Almost regularly the serpentine defects occurred only when the block was due to an indentation located anteriorly or posteriorly in the midline The defects were sometimes found at several levels in cases with multiple local stenotic parts but this was not obligatory They were occasionally found only at one level and then always related to the most cranially

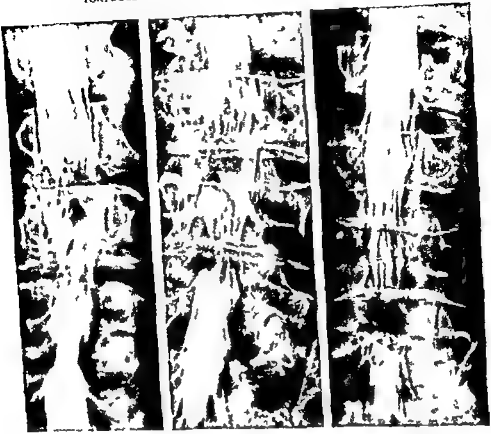

Fig 7 Fig 8 Fig. 9

Fig 7 Tortuous filling defects cranially to a partial block Two of these run for a long distance together with nerve roots having an ordinary course At operation a protruded disc was found with compressed nerve roots in addition to a few elongated nerve roots

Fig 8 Multiple defects due to protrusion Above the most cranial one a tortuous filling defect represents an elongated nerve root Ordinary longitudinal course of other nerve roots

Fig 9 Irregular tortuous filling defects restricted to a small area caudally to a partial block re presenting congested veins Ordinary course of nerve roots above and below the block

situated (Fig 8) In some of these cases the dura was opened at a subsequent opera tion but in none could a true elongation of the nerve roots be observed The observa tions at operation and at myelography suggest the tortuosity to be secondary to displacement in a cranial direction of the nerve roots which then due to the decreased space available became tortuous However in the individual case it may be impos sible to distinguish between redundant and displaced nerve roots at myelography The fact that sometimes one or two displaced roots appeared more tortuous and elongated than the other roots might be considered to indicate that the two types

i e the *actually elongated* roots and the compressed and displaced roots, may occur simultaneously

The roentgenologic differential diagnosis between the two different forms of nerve root abnormalities may be essential from a clinical point of view In the present 5 cases of confirmed root redundancy as well as in the cases reported by KONDO et coll and also by other authors the elongated nerve roots may occupy much of the intra dural space, forming a mass necessitating a dural decompression with a subsequent dural graft However, all of the present cases and all but one of the cases reported in the literature have in addition to the tortuous filling defects also local narrowing explaining the symptoms and signs The similarity between the now described ab normalities and those encountered in connection with arteriovenous malformations is evident and in no less than 5 of the 15 previously reported cases with root redun dancy an erroneous pre operative diagnosis of arteriovenous malformation had been made (CRESSMAN & PAWL SCHUT & GROFF, LOMBARDI FOX SORENSEN & WIRTHLIN) In 2 of these cases angiography was performed without any arteriovenous malforma tion being found (CRESSMAN & PAWL, SORENSEN & WIRTHLIN) In 8 cases in the present material the tortuous filling defects were of such a character that from a roentgenologic point of view a differentiation could not be made prompting a selective angiography of the lumbar arteries In none of these 8 cases was an arteriovenous malformation demonstrated

A conclusive differential diagnosis based on the myelographic findings seems to be impossible However the simultaneous presence of tortuous filling defects and a local narrowing of the canal suggest the nature of the defects indicating another pathology than an arteriovenous malformation

In a few of the present cases similar filling defects have been observed located below a local stenosis In these cases a local stasis of the veins may be considered as well as the presence of varicose veins or a venous angioma (TAVERAS & DALTON) (Fig 9) However such lesions have been extremely rare at this hospital

In conclusion tortuous filling defects are frequently found at lumbar myelography and appear to be related to a general or localized stenosis of the spinal canal In exceptional cases truly elongated nerve roots have been observed at the operation It has been discussed whether such an elongation is a congenital malformation (PAU & TURTAS) or a pathologic entity In the majority of cases the defects appear to be due to nerve roots displaced in a cranial direction from a narrowed part of the canal The filling defects are similar to those having a vascular origin of which the arteriovenous malformations are of particular interest In order to avoid unnecessary selective angiography of the lumbar arteries the recognition of the true nature of the defects is important The simultaneous occurrence of a stenotic or localized narrowed canal and tortuous defects related to this narrowing favours nerve roots as an explanation of the myelographic appearances and no further examinations should then be needed

SUMMARY

At lumbar myelography tortuous filling defects frequently occur in the presence of a marked local narrowing of the spinal canal This may lead to a displacement and compression of nerve roots which may partially or completely fill the subarachnoid space However truly elongated nerve roots have also been observed both at myelography and at operation Such elongation appears to be a congenital malformation The recognition of the true nature of tortuous filling defects is important with regard to differentiation against arteriovenous malformations and congested veins

ZUSAMMENFASSUNG

Bei der lumbalen Myelographie treten oftmals windende Fullungsdefekte auf bei dem Vorliegen einer kraftigen lokalen Verengerung des Spinalkanals Dieses kann zu einer Verlagerung und Kompression der Nervenwurzeln fuhren welche partiell oder komplett den Subarachnoidalraum ausfullen konnen Echte verlangerte Nervenwurzeln sind jedoch auch beobachtet worden sowohl bei der Myelographie wie der Operation Eine solche Verlängerung scheint eine kongenitale Missbildung zu sein Die Feststellung der wirklichen Natur von windenden Fullungsdefekten ist bedeutungsvoll hinsichtlich der Abgrenzung gegenuber arteriovenosen Malformationen und gestauter Venen

RESUME

Au cours de la radiculographie lombaire on constate souvent des défauts d opacification tortueux dans les cas de retrécissement local marqué du canal rachidien Ceci peut aboutir à un déplacement et à une compression des racines nerveuses qui peuvent remplir partiellement ou completement l espace sous arachnoïdien Cependant on a aussi observé des racines nerveuses reellement allongees aussi bien à la radiculographie qu à l opération Cette elongation paraît etre une malformation congénitale Il est important de reconnaitre la véritable nature des defauts d opacification tortueux pour le diagnostic differentiel avec les malformations artério veineuses et les veines dilatées

REFERENCES

CRESSMAN M R and PAWL R P Serpentine myelographic defect caused by a redundant nerve root J Neurosurg 28 (1968) 391

EHNI G MOIEL R H and BRAGG T G The redundant or knotted nerve root A clue to spondylotic cauda equina radiculopathy J Neurosurg 32 (1970) 252

FOX J Redundant nerve roots in the cauda equina J Neurosurg 30 (1969) 74

GARDNER N J Quoted by Sorensen & Wirthlin 1975

GULATI D R and ROUT D Myelographic block caused by redundant lumbar nerve root J Neurosurg 38 (1973) 504

HANRAETS P R M The degenerative back and its differential diagnosis Elsevier Amsterdam London New York Princeton 1959

KONDO A KOYAMA T ISHIKAWA J HANAKITA J and IWAKI K Redundant nerve roots of the cauda equina Acta neurochir 42 (1978) 209

i.e. the actually elongated roots and the compressed and displaced roots, may occur simultaneously.

The roentgenologic differential diagnosis between the two different forms of nerve root abnormalities may be essential from a clinical point of view. In the present 5 cases of confirmed root redundancy as well as in the cases reported by KONDO et coll. and also by other authors the elongated nerve roots may occupy much of the intradural space, forming a mass necessitating a dural decompression with a subsequent dural graft. However, all of the present cases and all but one of the cases reported in the literature, have, in addition to the tortuous filling defects, also local narrowing explaining the symptoms and signs. The similarity between the now described abnormalities and those encountered in connection with arteriovenous malformations is evident, and in no less than 5 of the 15 previously reported cases with root redundancy an erroneous pre-operative diagnosis of arteriovenous malformation had been made (CRESSMAN & PAWL, SCHUT & GROFF, LOMBARDI, FOX, SORENSEN & WIRTHLIN). In 2 of these cases angiography was performed without any arteriovenous malformation being found (CRESSMAN & PAWL, SORENSEN & WIRTHLIN). In 8 cases in the present material the tortuous filling defects were of such a character that from a roentgenologic point of view a differentiation could not be made prompting a selective angiography of the lumbar arteries. In none of these 8 cases was an arteriovenous malformation demonstrated.

A conclusive differential diagnosis based on the myelographic findings seems to be impossible. However, the simultaneous presence of tortuous filling defects and a local narrowing of the canal suggest the nature of the defects, indicating another pathology than an arteriovenous malformation.

In a few of the present cases similar filling defects have been observed located below a local stenosis. In these cases a local stasis of the veins may be considered as well as the presence of varicose veins or a venous angioma (TAVERAS & DALTON) (Fig. 9). However, such lesions have been extremely rare at this hospital.

In conclusion, tortuous filling defects are frequently found at lumbar myelography and appear to be related to a general or localized stenosis of the spinal canal. In exceptional cases truly elongated nerve roots have been observed at the operation. It has been discussed whether such an elongation is a congenital malformation (PAU & TURTAS) or a pathologic entity. In the majority of cases the defects appear to be due to nerve roots displaced in a cranial direction from a narrowed part of the canal. The filling defects are similar to those having a vascular origin, of which the arteriovenous malformations are of particular interest. In order to avoid unnecessary selective angiography of the lumbar arteries, the recognition of the true nature of the defects is important. The simultaneous occurrence of a stenotic or localized narrowed canal and tortuous defects related to this narrowing favours nerve roots as an explanation of the myelographic appearances and no further examinations should then be needed.

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SCINTIGRAPHY OF INDUCED MYOCARDIAL INFARCTS WITH $^{99}Tc^m$ GLUCONATE

H LUNDQUIST R LEWANDER J RAJS and B SARBY

During the past few years several isotopes have been used to detect myocardial infarcts Recently a new isotope $^{99}Tc^m$ gluconate has been investigated in experimentally induced myocardial infarcts in dogs (AHLBERG et coll 1978) The affinity of this compound for ischaemic myocardium was high and the uptake well corresponded to the extent of the myocardial injury determined at microscopy This report presents an evaluation of $^{99}Tc^m$ gluconate for detection of induced myocardial infarcts in vivo and an estimation of the infarct weight using a gamma camera connected on line to a computer

Material and Method

The gluconate complex was prepared with the technique previously described (AHLBERG et coll) The material consisted of 5 adult mongreal dogs weighing between 10 and 30 kg The animals were anaesthetized with intravenous phenobarbital intubated and ventilated in an AGA respirator with O_2 and N_2O in combination with pancuron bromide and neurolept analgesia intravenously In 4 dogs a coronary artery was occluded using a catheter technique described by SZAMOSI (1972) and modified by AHLBERG et coll The effect of the coronary occlusion was controlled on the ECG and at repeated coronary angiographies The blood pressure

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DE LANGE S A: Eine Anomalie der Cauda equina bei einer achondroplastischen Frau Acta neurochir 16 (1967) 114

LOMBARDI V Redundant nerve root of the cauda equina Neurology 19 (1969) 1223

PAU A and TURTAS S Redundant nerve roots of the cauda equina Acta neurochir 33 (1976) 311

SCHUT L and GROFF R A Redundant nerve roots as a cause of complete myelographic block J Neurosurg 28 (1968) 394

SORENSEN H F and WIRTHLIN A J Redundant nerve roots of the cauda equina Surg Neurol 3 (1975) 177

TAVERAS J A and DALTON C J Myelographic aspects of vascular malformations of the spinal cord Transactions of IX International Congress of Radiology Munich 1959 Thieme Stuttgart 1961

— and WOOD E H Diagnostic neuroradiology First edition Williams and Wilkins Co Baltimore 1964

THULIN C A EDNER G FODSTAD H SALFORD L and SVENDGAARD N A Redundant nerve roots of the cauda equina Acta neurochir 41 (1978) 115

VARUGHESE G Extradural extrusion of roots of the cauda equina Surg Neurol 5 (1976) 61

VERBIEST H A radicular syndrome from developmental narrowing of the lumbar vertebral canal J Bone Jt Surg 36 B (1954) 230

WILSON C B, Significance of the small lumbar spinal canal Cauda equina compression Syndromes due to spondylosis Part 3 Intermittent claudication J Neurosurg 31 (1969) 499

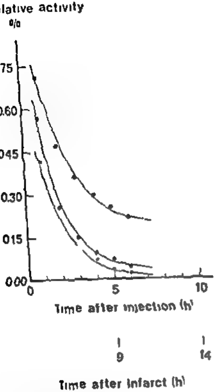

Fig. 2. Time activity curves for $^{99}Tc^{m}$ gluconate in the infarct (●), the normal myocard (◆) and the lung (★). (Measurements obtained from dog 3.)

approximate weight of the ischaemic myocardium in the tissue block was then calculated. Further details of the procedure have been described previously (AHLBERG et coll.).

Results

In all dogs the myocardial infarct could clearly be demonstrated on the gamma camera image already at six hours following the coronary artery occlusion (Fig. 1). The infarct corresponded to an area of increased isotope activity superimposed on the background radiation from the remaining parts of the heart. The localization and size of the infarct could roughly be estimated on the image. In the dog without coronary artery occlusion the isotope activity from the heart appeared uniformly dispersed.

After the isotope injection the rise of activity was followed by a rapid decrease in the normal myocardium and the lungs. However, in the infarct region the decrease was much slower with a maximum difference between the activities in the infarct region and normal myocardium about 3 h after the isotope injection (Fig. 2). The ratio between these activities increased successively during the experiments with maximum values between 2.0:1 and 4.5:1 (Fig. 3). On correction for the blood

Fig 1 Gamma camera image (analogue image from oscilloscope) in lateral projection *Uptake of $^{99}Tc^{m}$ gluconate in an infarct 6 h after coronary artery occlusion* heart border → infarct *region* ↔ *liver boundary*

and ECG were recorded throughout the experiments The remaining dog served as a control without induced myocardial infarct but otherwise run in the same way as the other animals The scintigraphy was performed with a General Electric gamma camera connected on line to an Intertechnique Cine 200 computer The recording was made with a high resolution collimator and an image matrix of 64 × 64 cells Three to four hours after the coronary artery occlusion 10 mCi $^{99}Tc^{m}$ gluconate was injected intravenously The transport of the isotope bolus through the heart and the large vessels was recorded at serial scintigraphy in intervals of two seconds to identify the heart chambers and the aorta An index system was used to outline five rectangular regions of interest the infarct the normal myocardium the lung the liver tissue and the blood background measured over the aorta These regions were stored as reference areas for the subsequent isotope analysis In order to quantitate the isotope uptake in these regions the gamma camera system was calibrated immediatly before each experiment with a standard activity in a phantom simulating the actual conditions of the in vivo measurements Every hour after the isotope injection analogue and digital gamma camera images were taken with an exposure time of 100 s or multiples of 100 s corresponding to about 5 × 10 counts Blood samples for determination of the clearance of the $^{99}Tc^{m}$ gluconate were collected as well

The animals were rapidly killed by interruption of the artificial respiration 12 to 14 h after the coronary artery occlusion and the heart was immediatly removed from the thoracic cavity The myocardium corresponding to the territory of the occluded artery was cut out weighed and saved for microscopic estimation of the extent of the ischaemic lesion expressed in per cent of the excised myocardium The

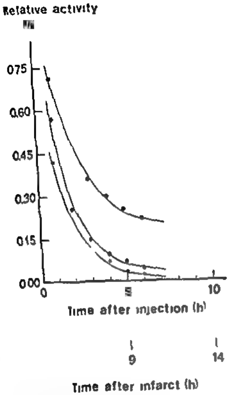

Fig 2 Time activity curves for $^{99}Tc^{m}$-gluconate in the infarct (●) the normal myocard (◆) and the lung (★) (Measurements obtained from dog 3)

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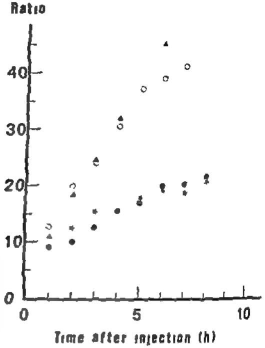

Fig 3 Ratio between the uptake of $^{99}Tc^{m}$ gluconate in the infarct and the normal myocard ★ = dog 1 ● = dog 2 ▲ = dog 3 ○ = dog 4

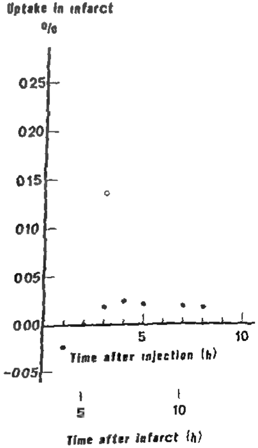

Fig 4 Time activity curves for $^{99}Tc^{m}$ gluconate in the infarct corrected for the blood background ★ = dog 1 ● = dog 2 ▲ = dog 3 ○ = dog 4

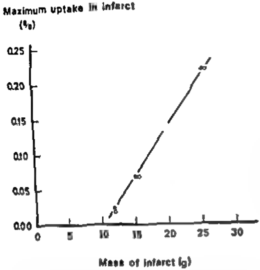

Fig 5 Relation between the uptake of $^{99}Tc^m$ gluconate in the infarct and the mass of the infarct obtained for dogs 1–4 ○ – isotope uptake in the infarct 3 h after isotope injection ● – isotope uptake at time of its maximum

background the maximum activity of the isotope in the infarct was found to occur 6 to 8 h after the coronary artery occlusion (Fig 4) The maximum activities of the infarcts of the 4 dogs differed considerably However the activities were closely correlated to the microscopically corrected weights of the corresponding infarcts (Fig 5) The correlation was destroyed if the infarct weight was not corrected for the extent of the lesion In the control animal no local increase of isotope activity in the heart could be recorded

The effective half time of the blood clearance of $^{99}Tc^m$ gluconate was approximatly 30 min (Fig 6) The accumulation of the isotope compound in the liver was rapid The maximum uptake was high (0 10–0 37°) and was reached after 2 to 3 h following the isotope injection In the control dog the maximum isotope accumulation in the liver occurred after 4 hours

Discussion

The requirements of isotope compounds for gamma camera imaging of myocardial infarcts are a high specificity for irreversible ischaemic myocardial cells no retention in adjacent organs and a fast reduction of blood clearance which implies a high ratio between the activity in the damaged myocardium and the surrounding tissue Currently used isotope compounds for positive infarct scanning all have a high affinity for myocardial infarcts The primary disadvantage with the phosphate compounds is the non specificity i e accumulation in the skeleton as well as in the ischaemic myocardium with high isotope activities in the ribs superimposing on the heart This renders the quantitative analysis of the activity in the myocardial infarct impossible However $^{99}Tc^m$ gluconate and $^{99}Tc^m$ heptogluconate do not accumulate

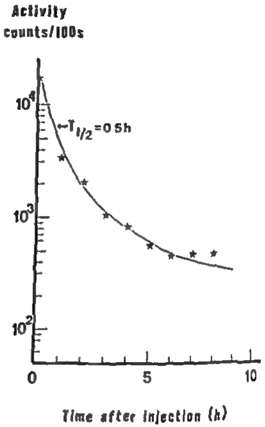

Fig 6 Blood clearance curve for $^{99}Tc^m$ gluconate

in the skeleton, thus making quantitative measurements possible (FINK BENNET et coll 1974, ROSSMAN et coll 1975) A high uptake of $^{99}Tc^m$ gluconate occurred in the liver It was closely time related to the uptake in the ischaemic myocardium in all dogs An infarct in that part of the heart facing the diaphragm may therefore be superimposed on the liver and overlooked This error can be avoided if gamma camera images also are taken in projections tangential to the diaphragmatic border between the heart and the liver

The accumulation of the isotope compound in irreversible myocardial cells is supposed to be caused by a redistribution of electrolytes beginning a few hours after coronary artery occlusion (SHEN & JENNINGS 1972) These changes coincide with the accumulation of $^{99}Tc^m$ gluconate resulting in an increasing isotope activity in the infarct region until a maximum is reached at about 7 hours At this time neutrophil infiltration and cell necrosis with oedema in the irreversibly injured myocardium have started During the progression of this process the isotope uptake gradually decreases Thus the accumulation of $^{99}Tc^m$ gluconate in the heart cells probably depends on the redistribution of electrolytes in the early phase of irreversible ischaemia and is not correlated to the ensuing process of cell destruction

In all dogs there was an exponential decrease of the activity of $^{99}Tc^m$ gluconate in the blood due to simultaneous elimination through the kidneys and accumulation in the liver The optimum time for imaging infarcts in dogs is about 3 to 4 h after the

isotope injection At this period the difference between the uptake in the infarct and the surrounding tissue reaches a maximum A close correlation was found between the maximum isotope uptake in the infarct regions and the microscopically corrected infarct weights Quantitative measurements of the uptake of ^{99}Tc^{m} gluconate in the infarct area with gamma camera technique may be a way to estimate the size of the infarct However the correlation line between the isotope uptake in the infarcts and the corrected infarct weights did not intersect origo This is due to a systematic error in the microscopic assessment of the extent of the infarct invariably the values of the corrected infarct weigths became too high Further details concerning the procedure of correction have been presented previously (AHLBERG et coll) The accumulation of ^{99}Tc^{m} gluconate in the liver was high in all experiments This contributes to the rapid decrease of the isotope compound in the blood and may be the reason why the gamma camera images of the infarcts are clearly demonstrated

SUMMARY

A new isotope compound ^{99}Tc^{m} gluconate for detection of myocardial infarction has been tested in dogs A close correlation was found between the isotope uptake measured in vivo with a gamma camera and the infarct weight of early irreversible myocardial infarcts

ZUSAMMENFASSUNG

Eine neue Isotopenverbindung ^{99}Tc^{m} Gluconat wurde zur Feststellung eines Myokard infarktes bei Hunden untersucht Eine enge Korrelation zwischen der Isotopenaufnahme gemessen in vivo mit einer Gammakamera und dem Infarktgewicht eines fruhzeitigen irreversiblen Myokardinfarktes wurde gefunden

RESUME

Un nouveau compose isotopique le gluconate de ^{99}Tc^{m} a été essaye pour la detection de l infarctus myocardique sur des chiens Les auteurs ont trouve une corrélation étroite entre la fixation isotopique mesuree in vivo au moyen d une gamma caméra et le poids de l infarctus dans les infarctus myocardiques irreversibles précoces

REFERENCES

AHLBERG N E BOIS-SVENSSON I CALISSENDORFF B LEWANDER R LUNDQUIST H and RAJS J Uptake of ^{99}Tc^{m} gluconate and early histologic findings in induced myocardial infarcts in dogs Acta radiol Diagnosis 19 (1978) 65

FINK BENNET D DWORKIN H J and LEE Y H Myocardial imaging of the acute infarct Radiology 113 (1974) 449

ROSSMAN D J ROULEAN J STRAUSS H W and PITT B Detection and size estimation of acute myocardial infarction using ^{99}Tc^{m} glucohepatonate J nucl Med 16 (1975) 980

— STRAUSS H W SIEGEL M E and PITT B Accumulation of $^{99}Tc^{m}$ glucoheptonate in acutely infarcted myocardium J nucl Med 16 (1975) 875

SHEN A and JENNINGS B Kinetics of calicum accumulation in acute myocardial ischemic injury Amer J Pathol 67 (1972) 441

SZAMOSI A Experimental occlusion of the coronary arteries in the closed chest dog A selective method Acta radiol Diagnosis 12 (1972) 545

(For further references see AHLBERG et coll)

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PULMONARY SYSTEMIC FLOW RATIOS IN ATRIAL SEPTAL DEFECT ASSESSED BY VENTRICULAR VOLUME MEASUREMENTS

H G RINGERTZ P STANGER and E CARLSSON

The magnitude of the left to right shunt in patients with an atrial septal defect is often expressed by the ratio between the pulmonary and the systemic blood flows The measurement of pulmonary and systemic blood flows by the Fick method requires accurate measurement of oxygen consumption as well as of pulmonary arterial systemic arterial and representative mixed venous oxygen contents In the presence of left to right atrial shunt the latter may be unobtainable Consequently systemic flow measurements may be considerably in error In addition relatively small errors in the measurement of oxygen contents may cause major errors in pulmonary blood flow calculations particularly in patients with large left to right shunts where the pulmonary arteriovenous oxygen content difference is small (FLAMM et coll 1969 LAKIER et coll 1975) The present communication describes a radiographic method for estimating pulmonary systemic flow ratios in patients with atrial septal defects and compares these measurements with values obtained by the Fick technique Such a combined method might corroborate otherwise questionable measurements or disclose discrepancies which would then require further exploration

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The right ventricular—left ventricular stroke volume ratio is equal to the pulmonary—systemic flow ratio When the shunt through an atrial septal defect is exclusively left to right, the difference between the right and the left ventricular stroke volumes is equal to the shunted volume per cardiac cycle

It has previously been demonstrated (CARLSSON et coll 1971) that similar values for right and left ventricular stroke volumes can be obtained by cineeardioangiographic measurements in patients without shunts or valvar insufficiencies Using the same technique right and left ventricular stroke volume measurements were made in 28 patients with atrial septal defects and were compared with pulmonary and systemic flow measurements by the Fick method

Material and Methods

During the period May 1969 to December 1974 28 patients with isolated secundum atrial septal defects i e without other shunts or valvar insufficiencies which might affect stroke volumes were catheterized at this hospital Three of these patients had slightly deformed mitral valves without insufficiency 6 had mild pulmonic flow gradients but without angiographic evidence of pulmonic stenosis 15 of the 28 patients were females The ages of the patients ranged from one week to 71 years with an average of 10 years and a median age of 4 years

All patients underwent right and left heart catheterization Biplane cineeardioangiography was performed with contrast medium injection into the right ventricle and assessment of the left ventricle during the levophase Chest films (p a and lateral) obtained within a week of the catheterization were available in 15 patients

Pulmonary and systemic flows were measured by the Fick method using a measured oxygen consumption in 10 cases and an assumed oxygen consumption (FIXLER et coll 1974) in 18 Oxygen contents were calculated using oxygen saturation values and a capacity based upon hemoglobin concentration as measured by the cyanmethemoglobin technique Oxygen saturations were measured either by an AO oximeter or derived from pH corrected PO_2 values using an oxyhemoglobin dissociation nomogram (SEVERINGHAUS 1958) When PO_2 was obtained the derived saturation was used for flow calculations in preference to oximeter values

Pulmonary arteriovenous oxygen differences were obtained using samples from a branch pulmonary artery and an appropriate left sided sample In the absence of a right to left shunt a mixed pulmonary venous oxygen content was obtained by left ventricular or systemic arterial sampling In the presence of a right to left atrial shunt a sample was obtained directly from a pulmonary vein Right to left atrial shunting was considered to be present if systemic arterial oxygen saturation or tension was low or less than pulmonary venous saturation

Systemic arteriovenous oxygen differences were obtained using left ventricular or systemic arterial samples and those obtained in the venae cavae Calculations using the values from the superior vena cava were performed in all cases In 15 patients

Table 1

Ranges for the cardioangiographic volume data of the 28 cases

	Right ventricle	Left ventricle
End diastolic volume (EDV)	32–173 ml	13–76 ml
End systolic volume (ESV)	9–76 ml	4–34 ml
Stroke volume (SV)	23–105 ml	8–49 ml
Ejection fraction (EF)	44–76	53–77

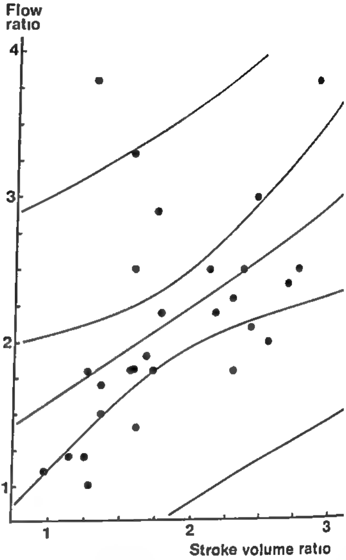
in whom values from the inferior vena cava were available systemic flows were also calculated using values both from the superior and inferior vena cava by the method of RIDGE & HARRISON (1970)

The radiography was performed using a biplane 16 mm General Electric cinesystem with 60 frames per second in each plane exposed alternately The volumes of the ventricles at end diastole and end systole were calculated according to the method of GOERKE & CARLSSON (1967) and included correction for right ventricular filling time (CARLSSON et coll) The corrected end diastolic right ventricular volume was calculated as the sum of the uncorrected end systolic volume and the corrected stroke volume The relative enlargement of the right ventricle was expressed as the ratio between the corrected right and left end diastolic ventricular volumes The ratio between the corrected right and left ventricular stroke volumes was us d as a measurement of the pulmonary to systemic flow ratio Ejection fractions were calculated as the ratio of uncorrected stroke volume to uncorrected end diastolic volume The total cardiac volume was calculated from the patient s p a and lateral chest films by the formula of RINGERTZ et coll (1966) These volumes were compared with the expected normal heart volume (RINGERTZ et coll) as calculated using the patient s body surface areas (DU BOIS & DU BOIS 1916) In the present material these areas varied between 0 19 and 1 69 m

Results

Table 1 summarizes the angiographic volume data for the 28 cases and includes ranges for right corrected and left ventricular end diastolic as well as end systolic volumes corrected stroke volumes and ejection fractions

The ratio of the angiographic right and left ventricular stroke volumes (SV_{RV}/SV_{LV}) and the Fick pulmonary to systemic flow ratio (Qp/Qs) and the relative right ventricular enlargement varied between 0 97 and 2 92 1 00 and 3 86 and 1 06 and 4 32 respectively Values obtained by the two different methods of assessing pulmonary to systemic flow ratio are plotted in the Figure The regression equation is $Qp/Qs = 0\ 908 + 0\ 675\ SV_{RV}/SV_{LV}$ with r having a value of 0 491 An ideal fit would have been represented by the equation $Qp/Qs = 0 + 1\ SV_{RV}/SV_{LV}$ and $r = 1$ In the 15 cases in



The ratio of the angiographic right and left ventricular stroke volumes along the x axis plotted versus the Fick pulmonary to systemic flow ratio for 28 patients

which the contents of the inferior vena cava were available the correlation was considerably better when both these values were used than when only the contents of the superior vena cava were used (r = 0 81)

In order to assess the effect of the shunt size on the ejection fraction the cases were divided into three groups of nearly equal size according to the magnitude of the right ventricular ejection fraction The average and standard deviation of stroke volume and end diastolic volume ratios were calculated for each group The results for the right and the left ventricles are presented in Table 2 An inverse relationship was found between shunt size and right ventricular ejection fraction i e the largest shunts had the smallest ejection fraction In contrast the left ventricular ejection fractions were normal (> 50 %) in all cases but one A plot of ejection fractions for different ages demonstrated no relationship

Table 2

Right and left ventricular ejection fractions

Right ventricular ejection fraction ( )	No of cases	Stroke volume ratio	End-diastolic volume ratio	Left ventricular ejection fraction ( )	No of cases	Stroke volume ratio	End diastolic volume ratio
< 56	9	2 2 ± 6	2 7 ± 8	< 64	10	1 9 ± 5	2 0 ± 6
56–65	10	1 8 ± 6	2 2 ± 7	64–70	10	2 1 ± 6	2 5 ± 9
65	9	1 6 ± 5	1 7 ± 5	> 70	8	1 5 ± 4	1 7 ± 4

Table 3

Heart diameters

Case No	Heart diameters (cm)			A Box volume (ml)	B Expected volume (ml)	Volume ratio (A/B)
1	4 5	3 4	3 8	38	96	0 60
4	6 6	5 1	4 5	151	157	0 96
5	7 4	5 2	5 4	208	221	0 94
6	8 9	6 8	5 9	357	402	1 77
8	9	5 9	5 3	247	258	0 96
10	8 9	5 9	5 9	310	324	0 96
14	9 1	7 6	7 3	505	368	1 37
16	9 4	7 4	6 4	445	416	1 07
17	10 5	8 7	6 5	494	450	1 32
18	10 4	9 4	6 0	587	533	1 10
21	11 8	9 6	7 5	850	649	1 31
22	10 9	8 7	8 4	797	598	1 33
25	11 6	9 1	9 3	982	875	1 12
26	16 0	14 4	10 3	2 373	986	2 41
27	13 9	11 1	9 5	1 466	1 065	1 38

The observed cardiac diameters measured on p a and lateral views are presented in Table 3 In addition are given the *observed box volume* and the corresponding calculated volume assessed from the body surface area using the formulae given by RINGERTZ et coll Finally the *observed and calculated* total heart volume ratio is given The regression between this ratio and the stroke volume ratio has a positive correlation with r = 0 83 When the *corresponding coefficient* was calculated relative to flow ratio it was found to be 0 85

The correlation coefficients are summarized in Table 4 The *significance* of each value is indicated

Table 4

Correlation coefficients for various combinations of flows and cardiac volumes

	No. of cases	Stroke volume ratio	Flow ratio
Flow ratio	28	0.49**	—
Right ventricular enlargement	28	0.91***	0.54**
Total heart volume	15	0.83***	0.85***
Right ventricular ejection fraction	28	−0.24	−0.42*
Left ventricular ejection fraction	28	−0.18	−0.27
		Inferior vena cava corrected flow ratio	*Flow ratio*
Stroke volume ratio	15	0.85***	0.81***

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

Discussion

Until recently cardioangiographic measurements of ventricular volumes have been confined largely to the left ventricle. The left ventricular cavity is more regularly shaped than that of the right ventricle, thereby allowing approximation of a manageable conventional geometric shape.

Volume measurements on post mortem ventricular casts (REEDY & CHAPMAN 1963, GOERKE & CARLSSON, GRAHAM et coll. 1973) as well as comparative right and left ventricular stroke volume calculations where the stroke volumes of the right and left ventricles are known to be equal (CARLSSON et coll.) have shown that right ventricular volumes can be calculated with almost the same accuracy as that of the left ventricle. Ventricular systolic volumes are generally more difficult to measure by cardioangiographic methods than the diastolic volume because the contour margins are less clear and the shape more irregular. In addition, fewer systolic post mortem casts are available for regression analysis. Therefore, stroke volume measurements, which require both systolic and diastolic volume measurements, may be less accurate than diastolic volume measurements alone. However, any statement on this point will remain speculative until more complete cast measurements or other methods for evaluation of the validity of ventricular volume determination become available. MATHEW et coll. (1976), in a cardioangiographic investigation of ventricular response to volume overload, found a consistent overestimate of pulmonary and systemic blood flow measured by the Fick method as compared to measurements

of the ventricular volume However right to left ventricular stroke volume ratios correlated well with the Fick flow ratios because both systemic and pulmonic flows increased proportionally when measured by the Fick method

The comparative measurement of the stroke volumes of the two ventricles requires selection of beats that are not ectopic or postectopic In other words the two ventricles must be measured in a similar functional state or if they are measured in different functional states the result of the measurements must be corrected for this difference Biventricular measurements require as a rule the injection of contrast medium into the right ventricle The function of this chamber is thereby often disturbed multiple extra systoles may occur and a beat after an extra systole may be measured The left ventricle on the other hand which is measured not until the contrast medium has passed the pulmonary circulation is not generally subjected to such disturbances Consequently the right ventricular volume was normalized against that of the left ventricle As a tool for such normalization the effective diastolic filling time was calculated by counting the number of cineradiographic frames during which filling occurred The ratio between the filling time of the two ventricles was used for correction of the actual measured diastolic right ventricular volume Such an approach has been found empirically to result in an improved correlation between stroke volumes in patients with known equal stroke volumes (CARLSSON et coll)

In patients with larger shunts the ejection fractions measured were found to be smaller than those in patients with smaller shunts This could be the result of errors in the measurement of large ventricles but it is also possible that the myocardium of the right ventricle was suffering and that therefore the ejection fractions were truly diminished

The correlation between the right ventricular–left ventricular stroke volume ratios on the one hand and the pulmonary to systemic blood flow ratios as obtained by the Fick method on the other is statistically significant in the 28 patients ($p<0.01$) In the 15 patients in whom blood samples from the superior and inferior venae cavae were available for estimating systemic flow the correlation coefficient was 0.81 (p 0.001) when the sample from the superior vena cava alone was used for calculation When samples both from the superior and the inferior venae cavae were used for the flow calculation (RIDGE & HARRISON 1970) the correlation coefficient was 0.85 In these 15 patients the differential right and left ventricular measurements are quite similar to the left to right shunt as obtained by the Fick method however there are some notable discrepancies between the two methods In one case for instance the Fick method gave a flow ratio of 3.86 while the cardioangiographic stroke volume ratio was only 1.29 The chest film demonstrated only a slightly enlarged heart with slightly increased pulmonary vascularity The measurements in the 15 patients for whom chest films were available show a highly significant correlation ($r=0.91$ $p<0.001$) between the total heart volume and the left to right shunt as measured by the stroke volume ratios It is reasonable to conclude that the volume measurements in this case are closer to the true values than are the blood gas analyses

particularly since the other diagnostic findings and the patient s clinical condition were more compatible with a small than with a large shunt

In one case no difference between the pulmonary and systemic flows as measured by the Fick method existed the ratio being 1 This appears to be a blood sampling problem as a left to right shunt was demonstrated on the levophase of the right ventriculography The cardioangiographic measurements show a stroke volume ratio of 1 25 indicating a small shunt

In 5 patients the stroke volume measurements indicated a considerably smaller left to right shunt than was indicated by the flow determinations In these patients the end diastolic volume ratios were closer to the shunt values found by the Fick method than were those calculated from angiographic stroke volume measurements In each case the right ventricular ejection fractions were less than 50 per cent All the other patients had ejection fractions larger than 50 per cent If the volume measurements were accurate this explains the discrepancy between the end diastolic volume ratios and the stroke volume ratios However it does not explain the differences between the Fick pulmonary systemic flow ratios on one hand and the stroke volume ratios on the other If it is assumed that, in addition to the left to right shunt a right to left shunt occurs through the atrial septal defect the discrepancies are explained The right ventricular end diastolic pressures in these patients as a group were higher than those found in the other patients and the systemic oxygen saturations were lower This indicates that some degree of right to left shunting may have occurred in addition to the left to right shunt explaining the reduced right to left stroke volume ratios as measured by cardioangiography

Considering the overall significant correlation between the flow ratios as established by blood gas analysis and the ventricular volume ratios obtained through cineangiographic measurements as well as the likely explanation of existing discrepancies it may be concluded that the cardioangiographic ventricular volume measurements are a valuable and accurate tool for the quantitation of left to right shunts in atrial septal defects particularly when the measurements are used in conjunction with classical physiologic methods

The need for a complementary method for measuring pulmonary blood flow in patients with atrial septal defects is augmented by the well known difficulties in applying conventional physiologic methods for this purpose e g quantitatively unknown blood flow of the venae cavae and coronary sinus small pulmonary systemic differences in oxygen saturations and inadequate mixing of indicators for dilution determinations

From a practical point of view it should be emphasized that shunt measurements at cardioangiography do not require any other procedures than those done for a complete anatomic diagnosis Biventricular volume measurements are routinely made in this laboratory for the evaluation of the contractile and relaxed state of the myocardium

SUMMARY

Twenty-eight patients with isolated secundum atrial septal defects were examined with right and left heart catheterization and cardioangiography The radiographically assessed pulmonary systemic stroke volume ratios and the physiologically determined pulmonary—systemic flow ratios correlated well However some striking discrepancies were observed the possible causes of which are discussed

ZUSAMMENFASSUNG

Achtundzwanzig Patienten mit isolierten sekundaren Atrium Septum Defekten wurden mit rechter und linker Herzkatheterisierung untersucht sowie Kardioangiographie Das rontgenologisch festgestellte Lungensystemkreislauf-Schlagvolumen Verhaltnis und die physiologisch bestimmten Lungensystemkreislauf-Durchfluss Verhaltnisse waren gut zu einander korreliert Jedoch wurden einige klare Diskrepanzen beobachtet deren moglichen Ursachen diskutiert werden

RESUME

Vingt huit malades ayant une communication inter auriculaire isolee (ostium secundum) ont été examines par cathetérisme cardiaque droit et gauche et par cardioangiographie Les rapports des volumes d ejection pulmonaire et systemique determinés radiographiquement et les rapports des debits pulmonaires systemiques déterminés physiologiquement etaient en bonne correlation Cependant certaines discordances frappantes ont eté observées les auteurs discutent leurs causes possibles

REFERENCES

CARLSSON E KEENE R J LEE P and GOERKE R J Angiocardiographic stroke volume correlation of the two cardiac ventricles in man Invest Radiol 6 (1971) 44

DU BOIS D and DU BOIS E F A formula to estimate the approximate surface area if height and weight be known Arch intern Med 17 (1916) 863

FIXLER D E CARRELL B S BROWNE R H WILLIS K and MILLER W E Oxygen consumption in infants and children during cardiac catheterization under different sedation regimes Circulation 50 (1974) 788

FLAMM M D COHN K E and HANCOCK E W Measurement of systemic cardiac output at rest and exercise in patients with atrial septal defect Amer J Cardiol 23 (1969) 258

GOERKE R J and CARLSSON E Calculation of right and left cardiac volumes Invest Radiol 2 (1967) 360

GRAHAM T P JARMAKANI J M ATWOOD G F and CANENT R V JR Right ventricular volume determinations in children Normal values and observations with volume or pressure overload Circulation 47 (1973) 144

LAKIER J B STANGER P HEYMANN M A HOFFMAN J I E and RUDOLPH A M Early onset of pulmonary vascular obstruction in patients with aortopulmonary transposition and intact ventricular septum Circulation 51 (1975) 875

MATHEW R THILENIUS O G and ARCILLA R A Comparative response of right and left ventricles to volume overload Cardiology 38 (1976) 209

REEDY T and CHAPMAN C B Measurement of right ventricular volume by cineangiofluorography Amer Heart J 66 (1963) 221

RIDGE J D and HARRISON J D Nomograms for determinations of mixed venous oxygen content and oxygen step up in atrial septal defect Amer Heart J 80 (1970) 575

RINGERTZ H RUDHE U WALLGREN G och GHAFFARPOUR R Röntgenologisk hjärtvolymbestämning hos barn (In Swedish) Läkartidningen 63 (1966) 3764

SEVERINGHAUS J W Oxyhemoglobin dissociation curve correction for temperature and pH variations in human blood J appl Physiol 12 (1958) 485

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FXPERIMENTAL AND CLINICAL EVALUATION OF CHOLANGIOGRAPHY WITH XERORADIOGRAPHY

B LUNDSTROM and G WICKMAN

The main problem at cholangiography may be briefly characterized as that of simultaneously demonstrating small calculi in wide as well as narrow bile ducts Previously (LUNDSTROM et coll 1976) the perceptibility of calculi of various sizes in ducts of different diameters with the tube potential and contrast medium concentration as variables was reported When a conventional screen film system was used as the recording medium optimum visibility was obtained at about 100 kV and a contrast medium concentration of 45 per cent The problem when photographic film is used is mainly the fact that when sufficient contrast in the image is attained the narrow exposure latitude of the film becomes a limiting factor when narrow and wide ducts are to be demonstrated simultaneously in the same image Compared to photographic film the xeroradiographic technique with its high contrast at high spatial frequencies in combination with its wide exposure latitude at low space frequencies would appear to be a superior recording medium The lower general sensitivity can be compensated for to some extent by excluding the grid and by an increase in the photon energy without losing too much image contrast These facts constitute the background for an investigation whether xeroradiography is an adequate method for cholangiography

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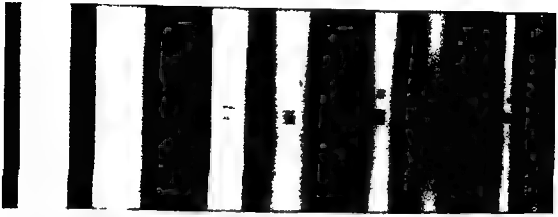


Fig 1 Calculi with diameters of 2 4 and [illegible] mm in ducts with diameters of 5 10 15 and 20 mm The ducts filled with contrast medium of concentrations 22 5 and 45 respectively Film exposed at 100 kV

Material and Methods

Experimental part

Conventional films Ducts with diameters of 5 10 15 and 20 mm were drilled in a homogeneous piece of plexiglass measuring 5 cm × 10 cm × 25 cm externally Plexiglass cylinders with diameters of 2 4 6 and 8 mm and of the same length as the diameters were placed in the ducts, which were then filled with diatrizoate (Urografin) in concentrations of 5, 10 22 5 and 45 per cent A 20 cm thick layer of water served as a body phantom Exposures were made at tube potentials of 80 100 120 140 and 160 kV The focus film distance was 100 cm A Potter Bucky diaphragm was used The nominal focal spot size used was 1 [illegible] mm × 1 0 mm Ilford Rapid R film and the universal intensifying screens used were Du Pont High Plus The exposure times were chosen to obtain a homogeneous optimum background density of 1 8 in the films

Xeroradiography The same experimental set up was used with the following changes The grid was excluded in order to minimize the absorbed dose and the Xerox cassettes were placed directly behind the water phantom The exposures were made with tube potentials of 100 120 140 160 and 180 kV The Rank Xerox S 125 equipment was used to load and develop the cassettes Negative processing with the process setting at D was used

Clinical part

Xeroradiography was performed in [illegible] patients in whom biliary duct calculi had been found at postoperative cholangiography using the current routine In these examinations with conventional film Urografin 45 per cent and a tube potential of 100 kV were used The Xerox prints made in the same patients were exposed at 180 kV and 20 to 60 mA with an FFD of 100 cm and the cassette placed directly behind the patient Negative processing was employed with the process setting at D

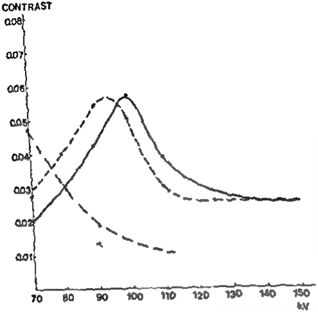


Fig 2 Radiographic contrast at a calculus diameter of 2 mm and a duct diameter of 20 mm at different contrast medium concentrations (—— 45 - - - 22 5 – – 10 5) and tube potentials Background density 1 8 units Visibility maximum at about 100 kV at the higher concentrations

Results

Experimental part

The results using the screen film system agreed with those reported previously (LUNDSTRÖM et coll) although calculi of another size were chosen and another intensifying screen (Figs 1 2) At about 100 kV a maximum of radiographic contrast was obtained i e detectability of small calculi in wide ducts at a contrast medium concentration of 22 to 45 per cent High tube potentials in connection with xeroradiography did not produce an appreciably lower degree of contrast visibility remained essentially unchanged at potentials between 100 and 180 kV at the same contrast medium concentrations When the medium concentrations were varied only small differences were observable at higher tube potentials detectability was slightly improved at higher concentrations (Fig 3) Thus the diagnostic possibilities were similar over a rather wide range of concentrations and tube potentials In any case they were not smaller at 180 kV and a 45 per cent concentration than at other values for these parameters When optimum images from the respective series were compared i e 100 kV with radiographic film and 180 kV with Xerox film and a concentration of 45 per cent in both cases the visibility of the calculi appeared to be a trifle improved in the Xerox images (Figs 1 3 c) Unfortunately comparative densitometry was not possible due to the fact that the screen film is transparent while the Xerox image is not

Clinical part

In the majority of cases the detected calculi were clearly visible both in the screen films and in the xerographic images and no definite difference was observable

(Fig 4) In 3 of the 10 cases with widened bile ducts (14–20 mm) the calculi were somewhat more distinctly discernible in ordinary radiographic films than in the xerographic images Unfortunately there were no cases with small calculi in wide ducts available for comparison

Radiation to the patient

A simple and frequently used method of comparing absorbed doses to the patient when different recording media are used is to measure or estimate the skin dose or exposure This is relevant when the media are compared in terms of the same radiation quality

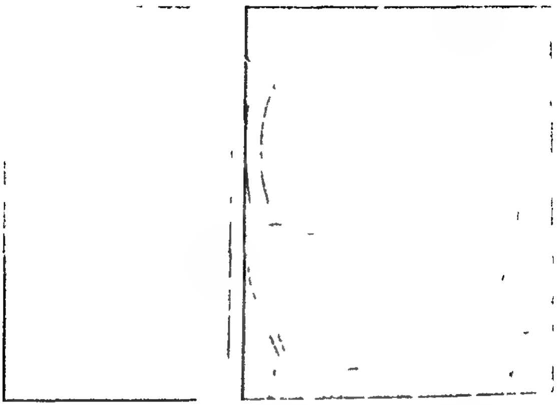
However the problem in the present situation may be briefly characterized as one of finding the patient dose at xeroradiography with a minimum but still acceptable image quality and comparing this dose with that for the screen film system at 100 kV The skin dose gives a misleading result since the deep dose distribution and scattered radiation vary significantly with the roentgen beam qualities used

The relevant parameter is the integral dose to the patient As a rough substitute for this figure the integral dose per cm in the central beam was calculated from data for a 20 cm thick semi infinite water slab given by CARLSSON (1963) and exposure measurements in free air for the different beam qualities used Fig 5 illustrates how the integral dose to the patient varies for the two recording media at different beam qualities It is evident that when xeroradiography is used the patient dose will be most favourable at the highest tube potential being about four times higher than the dose for the screen film system

Discussion

The xerographic technique has been tried in a number of different types of examinations including cholecystography (EISENSCHER et coll 1975) but it seems not to have been evaluated for cholangiography The narrow exposure latitude of the conventional screen film constitutes an important limiting factor in cholangiography for demonstrating small calculi in wide bile ducts The fact that the degree of diagnostic reliability under such conditions may be relatively low has been pointed out by for instance LINDSKOG (1970) and HALL et coll (1973) The wider exposure latitude of the Xerox plate makes it possible to demonstrate in the same image objects with great differences in attenuation This property is evident in the present experimental part which supports the assumption that the xerographic technique might offer certain diagnostic advantages One of the reasons why the xerographic technique has not come into use for cholangiography is probably its relative insensitivity vis à vis modern film screen combinations The calculated integral doses showed that the

Fig 3 Xeroradiography The same calculus and duct diameters as in Fig 1 The contrast medium concentration is a) 22 5 b) 5 c) 45 and d) 10 The tube potential is 120 kV in (a) and (b) and 180 kV in (c) and (d)



a b

Fig 4 Postoperative cholangiography with conventional film exposed at 100 kV and xeroradiography exposed at 180 kV The calculus in the common bile duct measured 6 mm in diameter

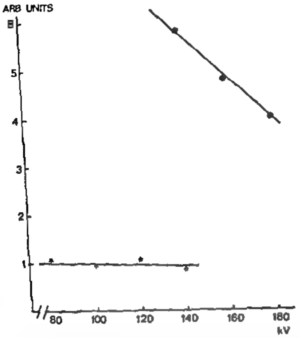


Fig 5 Integral absorbed dose (arb units) to the patient for conventional film ( ) and xeroradiography (●)

dose at xeroradiography was less at a tube potential of 180 kV than at lower potentials being about 4 times higher than at 100 kV using ordinary radiographic film The exposure time can also be kept at a reasonably low level at this tube potential even in stout patients No disadvantages of using a high tube potential were noted which might have been the case if there had been superimposed skeletal parts (HEMMINGSSON & LÖFROTH 1976) Thus in theory the xerographic technique should be diagnostically superior to the conventional screen film technique—and this was not contradicted by the model experiment—but in the actual clinical application its diagnostic reliability was found to be slightly lower in 3 of the 10 patients The reason for this is not clear Perhaps the xerographic system was not fully optimally adjusted It may also be due to the fact that interference from structures in other planes than the one under examination produced too much confusing information

Other complicating factors in the practical application was due to the fact that the Xerox cassette was placed directly under the patient and as a result neither the automatic exposure mechanism nor fluoroscopic control could be employed The Xerox image is also reversed when the cassette is placed under the patient s back and the overcouch tube used Another practical difficulty is that in their present design the Xerox cassettes are too thick to fit into ordinary cassette holders Even if it was not so the grid must be removed to avoid unacceptably high radiation doses If these different practical difficulties are overcome and if in addition the Xerox system can be rendered considerably more sensitive xeroradiography in cholangio-

graphy should have the potential to become a method that can afford a higher degree of diagnostic reliability

SUMMARY

Conventional screen film radiography is compared with xeroradiography in an experimental model for cholangiography The wider exposure latitude of the xerographic technique confers certain diagnostic advantages However the actual clinical application presents practical difficulties which combined with low sensitivity are of such a nature that the method can hardly be considered suitable at the present time If certain improvements can be made xeroradiography could become a superior method for radiography of the bile ducts

ZUSAMMENFASSUNG

Die konventionelle Radiographie mit Verstärkerfolien und Film wird mit Xeroradiographie an einem experimentellen Modell fur Cholangiographie verglichen Die grossere Expositionsbreite der xerographischen Technik bedeutet gewisse diagnostische Vorteile Die aktuelle klinische Anwendung bietet jedoch praktische Schwierigkeiten welche vereint mit niedriger Empfindlichkeit von solcher Natur sind dass die Methode gegenwärtig kaum als brauchbar angesehen werden kann Sollten gewisse Verbesserungen gemacht werden konnen konnte die Xeroradiographie eine uberlegene Methode fur die Darstellung der Gallenwege werden

RÉSUMÉ

Les auteurs ont comparé sur un modèle expérimental pour la cholangiographie la radiographie classique avec des films et des écrans et la xéroradiographie La plus grande latitude d exposition de la technique xérographique confère certains avantages diagnostiques Cependant l application clinique réelle présente certaines difficultés pratiques qui associés avec la faible sensibilité sont d une nature telle que la méthode peut difficilement etre considérée comme utilisable à l heure actuelle Si on peut réaliser certaines améliorations la xérographie pourrait devenir une méthode supérieure pour la radiographie des canaux biliaires

REFERENCES

CARLSSON C Determination of integral absorbed dose from exposure measurements Acta radiol Ther Phys Biol 1 (1963) 433

EISENSCHER A BOURGOIN A AUCANT D TUETEY B et WEILL F Apport de la xérographie à la découverte de calculs biliaires radiotransparents J Radiol Électrol 56 (1975) 903

HALL R C SAKIYALAK P KIM S K ROGERS L B and WEBB W R Failure of operative cholangiography to prevent retained common duct stones Amer J Surg 125 (1973) 51

HEMMINGSSON A and LÖFROTH P O Xeroradiography and conventional radiography in examination of the larynx Acta radiol Diagnosis 17 (1976) 723

LINDSKOG B Evaluation of operative cholangiography in gallstone surgery with special reference to residual stones Thesis Lund 1970

LUNDSTRÖM B RYDH A and WICKMAN G Experimental evaluation of tube potential and contrast medium concentration for cholangiography Acta radiol Diagnosis 17 (1976) 353

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COMPLICATIONS AT BALLOON CATHETER ANGIOGRAPHY

Experiments in rabbits and dogs

R JENSEN and T OLIN

Balloon catheters are of value in angiography and therapy (WHOLEY et coll 1970 JENSEN & OLIN 1972) An evaluation of possible complications has been performed and is now reported

Material and Methods

The experiments were performed in 6 rabbits and 6 mongrel dogs In the rabbits general anaesthesia was obtained with intravenous pentobarbitone sodium (Mebumal sodium ACO Sweden) A catheter (OPP 60 Portex England OD/ID 1 22/0 76 mm) with six side holes close to the tapered tip was introduced into the femoral artery The contrast medium meglumine metrizoate (Isopaque Cerebral Nyegaard Norway) was injected through the catheter by a high speed pressure injector (VeReCe Kistner Sweden) and the injection rate continuously registered on a polygraph Exposure data FFD 90 cm nominal focal spot 0 3 mm 3 to 10 mAs 0 03 to 0 08 s and 85 to 100 kV Rubin high definition screens were used with an AOT *film changer* (Siemens Elema Sweden) Examinations were made in a p and lateral projections The catheter was then withdrawn and was *replaced* by a balloon catheter This catheter (OPP 60) was provided with a home made balloon at its tapered and bent

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tip as previously described (JENSEN & OLIN). The major branches of the abdominal aorta were catheterized in turn and the balloon was inflated with about 0.01 to 0.03 ml contrast medium for 2 min. The balloon catheter was then withdrawn and substituted by a catheter shaped for aortography and then by a catheter shaped for selective catheterization of the abdominal arteries. After the angiography had been completed the catheter was withdrawn and the femoral artery was ligated. About 12 weeks later, a repeat examination was made in 3 of the rabbits including aortography in two projections and selective angiography of the abdominal arteries. The animals were then killed and the abdominal aorta and its branches were removed en bloc for microscopy.

The dogs had a body weight of 12 to 15 kg and were examined in a similar way as the rabbits. Aortographies were obtained in two projections using a catheter (Ödman-Ledin, Kifa, Sweden OD/ID 1.8/1.2 mm) introduced into the femoral artery. Exposure data: 10 mAs, 0.08 s, 95 to 100 kV. Saphir screens were used. The balloon catheter in this series was a double lumen catheter (7.5 F, 2.5 mm, Edwards Laboratories, USA) according to WHOLEY et coll. (1970). Before its introduction into the animal, the balloon was filled with contrast medium to make it possible to estimate the size and to control the shape of the balloon. The balloon was inflated with about 0.1 to 0.3 ml contrast medium and deflated after 2 min when positioned in the proper artery. Aortography and selective angiography were performed with the balloon catheter deflated. The incision in the femoral artery was then sutured with silk 6/0. Repeat angiographies were performed 2 to 12 weeks later. Eight ml contrast medium was used for injections into the aorta, the coeliac axis, and the superior mesenteric artery, and 5 ml for the renal artery. Isopaque Cerebral was employed for selective angiography and Isopaque Coronar for aortography. Twofold to threefold direct magnification was used and the diameters of the vessels before and after distension were measured on the films. Magnification adjustment was made with a magnifying glass with a scale graduated in tenths of a millimetre. The diameters were measured in the same way on the repeat films. The measuring procedure was repeated ten times for each film and the mean value calculated for each diameter. As it is difficult exactly to estimate the border lines of the vessels on the film, the error of the diameters were calculated according to the formula

$$\frac{D}{V} = \frac{A}{C}$$

$$D = \frac{V \cdot A}{C}$$

where D = diameter of the vessel, V = diameter of the vessel measured on the film, A = diameter of the catheter, 1.9 mm, C = diameter of the catheter measured on the film.

Taking the logarithm and differentiating: $\log D = \log V + \log A - \log C$

$$\frac{\partial D}{\partial V}\cdot\frac{1}{D} = \frac{1}{V}$$

$$\frac{\partial D}{\partial C}\cdot\frac{1}{D} = -\frac{1}{C}$$

$$\frac{\partial D}{\partial V} = \frac{D}{V}$$

$$\frac{\partial D}{\partial C} = -\frac{D}{C}$$

The following formula was used (GRAHN & HERTZ 1971, p. 63):

$$\Delta D = \pm\sqrt{\left(\frac{\partial D}{\partial V}\Delta V\right)^2 + \left(\frac{\partial D}{\partial C}\Delta C\right)^2}$$

$$\Delta D = \pm\frac{1}{C}\sqrt{(1.9\ \Delta V)^2 + \left(\frac{1.9\ V}{C}\ \Delta C\right)^2}$$

$$\Delta D = \pm\frac{1.9}{C}\sqrt{(\Delta V)^2 + \left(\frac{V}{C}\Delta C\right)^2}$$

$$\Delta V^2 = \frac{\sum_{1}^{n}(V - \bar{V})^2}{n(n-1)}$$

$$\Delta C \leq 0.1\ \text{mm}$$

The edges of the catheter are not difficult to distinguish and the error in the measurement of catheter diameter did not exceed 0.1 mm. The error in the estimation of the vessel and balloon diameters lies between 0.1 and 0.2 mm.

Results

The experiments in the rabbits revealed that there was a very small margin between just sufficient occlusion of an artery and overdistension of the vessel. Little difference existed between the volumes injected and differences in the injection pressure felt by hand on the piston of the syringe were imperceptible. The injury was usually greater in relatively small vessels such as the renal arteries in contrast to the superior mesenteric artery. The lesion often appeared severe after the balloon was deflated (Fig. 1). Dilatation of the vessel was sometimes evident and a very strong spasm of the vessel occurred distal to the dilatation. Microscopic examination 2 to 12 weeks later revealed injury to the internal elastic lamina and the tunica media. When a marked overdistension had been made all three layers of the arterial wall could be injured. The 12 week repeat angiography demonstrated regression of the injury to the artery and microscopically a certain degree of healing had occurred. To investigate

Fig 1 a) Abdominal aortography of a rabbit before balloon distension b) Immediately after balloon distension (60–70) of the renal arteries Dilatation of the arteries is partially maintained Marked spasm of the left renal artery distal to the dilatation c) Twelve weeks later Selective nephroangiography on the right side Normal d) Twelve weeks later Selective nephroangiography on the left side Remaining minimal irregularities of the artery Microscopy revealed only minor injury to the internal elastic lamina

whether the preparation of the specimen per se could cause arterial injury the aorta and its main branches were removed en bloc from a rabbit in which no balloon angiography or selective angiography had been performed At microscopy lesions were identified in the internal elastic laminae of 2 vessels of 4 Thus injury to the internal elastic lamina is often secondary to the preparation

The measurements in dogs are graphically illustrated in Figs 2 and 3 The diameter of the renal arteries the superior mesenteric artery and the coeliac axis are demon

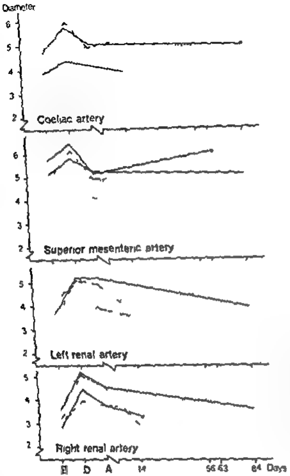


Fig. 2 Diameter (mm) of abdominal arteries in six dogs B = Before balloon distension D = During distension A = *After* distension When the balloon is inflated the caliber increases between 10 and 70 After deflation of the balloon the vessel often returns to normal caliber Microscopy after repeat angiography sometimes revealed injury to the vessel wall O = No damage -•- = Injury to the internal elastic lamina ● = Injury to the internal elastic lamina and the tunica media

strated before during and immediately after distension with a balloon catheter The dilatation of the arteries varied A strong balloon distension of an artery usually diminished or disappeared at exsufflation Severe overdistension was more apt to occur in small vessels Thus it was more common in the renal artery than in the superior mesenteric artery (Figs 4 5) Major injury revealed at microscopy corresponded to continued dilatation of the artery at angiography A dilatation was evident in 8 vessels immediately after balloon distension but at repeat angiography some weeks later a small widening remained in 3 vessels only Microscopy of these vessels revealed rather extensive injury to the internal elastic lamina and the tunica media In the remaining vessels where no abnormality was visible on the films no injury or only small lesions of the internal elastic lamina were identifiable at microscopy Vascular injury was not common in arteries with an internal diameter of 4

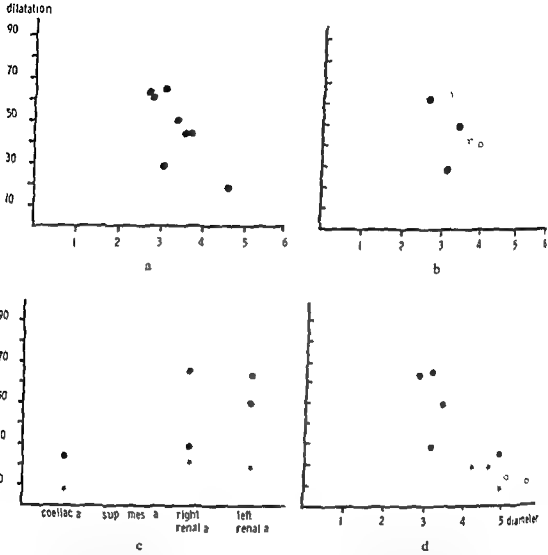


Fig 3 Diameter (mm) of abdominal arteries in dogs a) immediately after distension by the balloon and b) dilatation at *repeat angiography* *No dilatation of the arteries apparent* when the diameter of the vessel is about 4 mm or more and the distension not over 20 At repeat angiography most of the vessels look normal ● Dilatation ○ No dilatation c) Dilatation of abdominal arteries and d) degree of microscopic abnormality In the region without dilatation at angiography microscopy revealed no abnormality or only injury to the internal elastic lamina ○ No abnormality * Injury to internal elastic lamina ● Injury to internal elastic lamina and tunica media

mm or more but was rather common in arteries with an internal diameter of 3 mm or less Injury to the adventitia was not encountered at any of the experiments in dogs The repeat angiographies demonstrated that no stenosis of the arteries had developed during the observation period which extended over 2 to 12 weeks

In 3 instances the catheter jumped out of a vessel and back into the aorta when the balloon was dilated (Fig 6) The ellipsoid deformation of the balloon then disappeared although it was sufficiently filled In these cases the diameter of the balloon

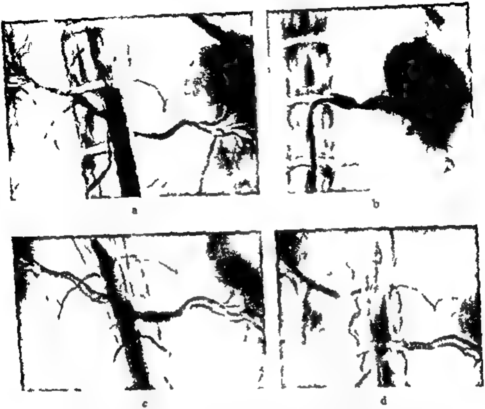
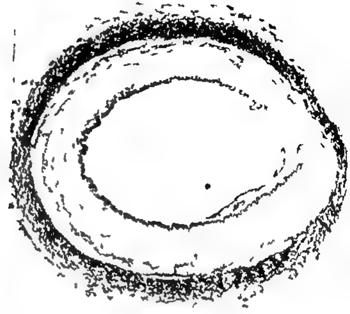


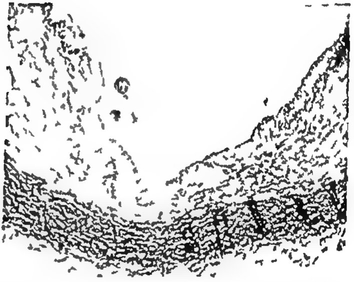
Fig 4 a) Nephroangiography in a normal dog b) Balloon catheter inflated in the renal artery c) Aortography immediately after deflation of the balloon Smooth widening of both renal arteries by about 50 d) Aortography two weeks later Only slight persistent widening of the left renal artery

exceeded the diameter of the vessel by between 50 and 90 per cent Injury to the internal elastic lamina and the tunica media was later revealed in 2 of the 3 arteries although no deformation of the vessels was evident on the films and the distension must have been very brief No injury was found in one of the 3 vessels from which the balloon presumably had jumped out during insufflation The measurements of the diameters of these vessels are not included in Figs 2 and 3

Direct measurement of the force exerted by the balloon on the walls of a vessel was made as follows Channels with a diameter of 4 0 6 0 and 8 0 mm respectively were drilled in a piece of acrylic plastic (Fig 7) The piece was then split lengthwise and a strain gauge was firmly fixed to its top The balloon was inflated in each channel in turn The forces exerted on the strain gauge are plotted against the volume injected in Fig 8 Inflation of the balloon with a very small volume will exert a strong expanding force in a 4 mm channel but only a small force in a 8 mm channel



a



b

Fig 5 Same dog as in Fig 4 *Left renal artery Extensive injury to internal elastic lamina and tunica media Minor aneurysmatic dilatation Magnification* 40 and 60

Discussion

The blood pressure or an inflated balloon exerts a stress on the arterial wall The *stress* $t_s = (p\ r)/t$ *where* p *pressure* r *inner radius and* t *wall thickness* The variation in diameter of an artery with the applied pressure can indicate elasticity *viscoelasticity or plasticity* (BADER 1963) Elasticity *implies that a constant relation* between pressure and diameter exists often expressed by Young's modulus of elasticity When unloaded a *perfectly elastic material will immediately go back to* the original size Above a certain *load an elastic material will be deformed* and will

Fig 6 a) Balloon catheter in superior mesenteric artery of a dog The inflated balloon is deformed by the artery b) The balloon has jumped out of the artery into the aorta and regained its spherical shape

not regain its shape when it is unloaded Viscoelasticity means that the elastic action is damped by a viscous one The diameter then depends not only on the pressure but also on the velocity with which it is applied When unloaded the material will slowly return to the original size A material is called plastic when it is deformed on loading and has a tendency to retain its new shape The arterial wall is not homogeneous but is composed of collagen tissue elastic tissue and smooth muscles The proportions of these components vary with species type of artery and age When overloaded the collageneous tissue will behave as a plastic material If smooth muscles are extended slowly they behave like a plastic material whereas on rapid extension their response is viscoelastic Another factor to bear in mind is that the smooth muscles are excited by distension a response which is considered to account for the so-called autoregulation of blood flow in for example the kidney Finally the smooth muscles in the vessel wall receive sympathetic and parasympathetic innervation All these factors must be borne in mind when assessing the effect of balloon catheters on blood vessels

When a balloon in an artery is sufficiently inflated it will establish contact about its equator with the inner wall of the vessel The pressure exerted on the wall is not as great as the pressure inside the balloon since some of this pressure is counteracted by the rubber membrane of the balloon On further inflation the area of contact with the wall broadens and the balloon assumes a shape that to a certain extent is a mould of the artery The pressure then exerted on the artery is sufficient for distension to occur At moderate pressures this process is probably viscoelastic and the artery will slowly regain its shape after deflation of the balloon At higher pressures

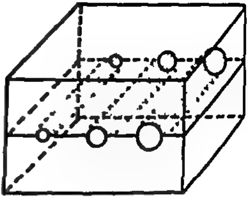


Fig 7 Piece of plastic with three holes drilled for measurement of the force exerted by balloon catheters

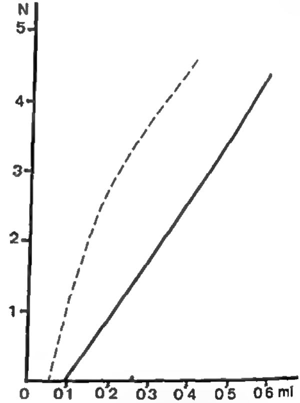


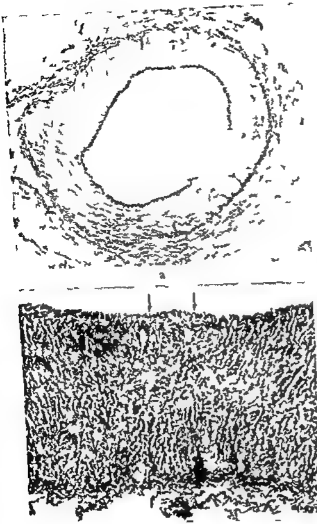
Fig 8 Force exerted at different degrees of balloon inflation Diameter --- 4 mm —— 6 mm 8 mm

the distension of the artery will be a plastic process i e dilatation of the artery will be maintained after deflation of the balloon On distension the smooth muscles in the wall will react to produce constriction spasm of the artery sometimes occurred immediately after deflation of the balloon

The volume which has to be injected into a balloon catheter in order to occlude an artery varies with the type of catheter used The small home made balloons used in rabbits have a spherical shape The volume of a sphere is

$$V=\frac{4\pi r^3}{3}$$

where r = inner radius



a

b

Fig 9 Microscopy of a renal artery nine weeks after a 20 distension Only small rupture of the internal elastic lamina (→) Similar lesions were also found in vessels which had *not* been distended Magnification about 40 and 100

The renal arteries of the rabbits used had an inner diameter of about 2 0 mm (mean 2 04) The volume of a sphere which is just large enough to occlude an artery of this calibre is 0 004 ml Empirically it was found necessary to inject a volume of about 0 01 ml in order to obtain complete occlusion The difference must be due to minor leakage or to the fact that the catheter contains air which is compressed when the balloon is filled

The balloon used in the dogs had another shape since it was fixed to the catheter at both ends The volume of such a revolution ellipsoid is

$$V = \frac{4\pi \ ab^2}{3}$$

where a = half the length of the balloon (along the catheter) and b = transverse radius of the balloon *For the catheter in question a = 3 1 mm* The volume of the piece of catheter inside the balloon has to be subtracted and is about 28 mm³ The renal artery of a 15 to 20 kg dog has an inner diameter of about 3 4 mm (mean value 3 44 r = 1 72 mm) The volume theoretically necessary for occlusion of this vessel is 0 01 ml In practice a volume of about 0 1 ml was necessary and the discrepancy may again be ascribed to air in the catheter and leakage

Balloon catheters can easily provoke injury to a vessel when they are inflated without care The risk increases as vessel size diminishes One explanation for this could be that there is a lesser amount of elastic tissue *in relation to the* amount of smooth muscles in a smaller vessel Moreover experiments in a plastic model demonstrated that a much stronger force was exerted at inflation of the balloon catheter in a small *vessel than in a large one In arteries with a diameter of 4 mm or more the risk is* minimal if the increase in the diameter of the vessel does not exceed 20 per cent (Fig 9) The small injuries to internal elastic lamina might have been produced by the preparation of arteries for microscopy

It is recommended to estimate the diameter of the vessel at an ordinary angiography in order to minimize the risk of injury Then appropriate insufflation of the balloon can be obtained without overdistension of the vessel

Acknowledgements

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SUMMARY

Overdistension of a balloon catheter may injure an artery and this risk increases with *decreasing vessel calibre Before balloon occlusion an estimation of the calibre of the vessel* at a preliminary angiography is recommended

ZUSAMMENFASSUNG

Überdehnung von Ballonkathetern kann eine Arterie schädigen und dieses Risiko steigt mit abfallendem Kaliber des Gefässes Bevor einer Ballon Okklusion wird empfohlen dass der Gefässdiameter mit Hilfe einer preliminären Angiographie bestimmt wird

RÉSUMÉ

La surdistension d un ballonnet de catheter peut léser une artère et ce risque augmente à mesure *que le calibre du vaisseau diminue Avant d occlure l artère avec le* ballonnet il est recommandé de faire une angiographie préliminaire

REFERENCES

BADER H The anatomy and physiology of the vascular wall *In* Handbook of physiology Section 2 Circulation volume II chapter 26 p 865 American Physiological Society Washington 1963

GRAHN L och HERTZ H Fysikalisk matteknik fysik (In Swedish) Almqvist & Wiksell Stockholm 1971

JENSEN R and OLIN T Balloon catheters in angiography An experimental investigation in rabbits Acta radiol Diagnosis 12 (1972) 271

WHOLEY M H STOCKDALE R and HONG T K A percutaneous balloon catheter for immediate control of hemorrhage Radiology 95 (1970) 65

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TRANSCATHETER EMBOLIZATION IN A HAEMOPHILIAC WITH POST-TRAUMATIC RENAL HAEMORRHAGE

Report of a case

M KLAMUT M SZCZERBO TROJANOWSKA J KOWALEWSKI and A NOWAKOWSKI

The treatment of renal trauma in a haemophiliac is a complex and uncertain procedure Surgical intervention for control of massive renal haemorrhage after trauma generally results in nephrectomy (SCOTT et coll 1963 LUCEY et coll 1972) Operation can only be performed when a large amount of cryoprecipitate is available Since renal haemorrhage in haemophiliac is a life threatening condition trans catheter embolization provides a valuable alternative to surgery (BOOKSTEIN & GOLDSTEIN 1973, CHUANG et coll 1975 SILBER et coll 1976)

Case report

A 30 year old man with severe haemophilia A blood group A Rh positive was admitted to this hospital because of renal haemorrhage following trauma of the left lumbar region and pain in the left flank The urine was haemorrhagic and contained 9 27 per cent protein The renal function was normal Blood urea nitrogen 449 5 mmol serum creatinine 9 2 mmol Replacement therapy with group A cryoprecipitate (10 bags i e about 2 000 IU per day) was begun Transfusion with 1 200 ml erythrocyte mass was given and supported with spasmolytics and analgetics After 3 days the red blood cells in urine were reduced to 20 per high power field and the patient had no more pain Cryoprecipitate was discontinued

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a b

Selective left renal angiography a) Arterial phase Filling of haematoma in the middle and lower pole b) After embolization Occlusion of main branches of the renal artery A subcapsular artery and adrenal arteries are patent

Four days later recurrent lumbar pain developed with macroscopic haematuria the haemoglobin level was 6 5 mmol/l and the red blood cells 2 5 T/l Urinary excretion was undisturbed The previous therapy was repeated No circulating anticoagulants were present in the blood serum and 12 hours after cryoprecipitate infusion factor VIII level remained between 15 and 20 per cent

Urography demonstrated normal function of the right kidney but no excretion on the left side Operation was not considered because of high risks in patients with severe haemophilia Instead it was decided to perform angiography combined with an embolizing procedure of the bleeding vessels On the left side a large haematoma was found in the middle and lower pole of the kidney (Fig. a) but no abnormality on the right side

Autologous clots and Spongostan cut into 2 mm × 2 mm × 5 mm cubes and immersed in physiologic saline were used for embolization A grey Ödman catheter was placed in the left renal artery and 30 ml of autologous clots and then [illegible] Spongostan cubes were injected Repeated angiography demonstrated that the two main branches of the renal artery were occluded (Fig b) No filling of the haematoma was obtained

During a few hours after embolization the patient complained of left lumbar pain which was relieved with analgetics Body temperature arterial pressure pulse and urinary excretion were normal No excessive bleeding or haematoma occurred at the site of puncture which may be due to the infusion of cryoprecipitate giving 15 to 20 per cent factor VIII level after 12 hours The red blood cells in the urine decreased rapidly and had completely disappeared on the fifth day On the eighth day after embolization the body temperature rose to 38 2 C and ampicilline was replaced by gentamicine and cephalothin

The patient was discharged from the hospital in good condition and returned to work Eighteen months follow up revealed no evidence of hypertension or renal failure Feeling

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RADIOGRAPHIC APPEARANCES IN CROHN S DISEASE

I Accuracy of radiographic methods

J HILDELL C LINDSTROM and A WENCKERT

In the preoperative evaluation of patients with Crohn s disease radiography still remains the most important means for establishing a diagnosis and defining the extent of the disease

The radiographic features of the disease have been described by several authors (KANTOR 1934 MARSHAK & LINDNER 1970 BRAHME 1971 KEMP HARPER 1971 SELLINK 1971 1974 STANLEY et coll 1971 ENGELHOLM & PEETERS 1976 LAUFER & HAMILTON 1976) Different examination techniques have been used but generally accepted criteria are based mainly on findings with the high kV barium enema and the conventional follow through technique and are essentially those suggested by MARSHAK and co-workers (1955 1970 1975) These criteria do not include the diagnosis of minor mucosal ulcers which are well known to the pathologist (MORSON 1972) and also to the surgeon Consequently the diagnostic accuracy of radiography has been a matter of dispute Discrepancies between the extent of the disease as assessed at radiography and at operation or endoscopy are often commented upon in the clinical literature (ATWELL et coll 1965 WILLIAMS 1972 MEUWISSEN et coll 1976 VAN TRAPPEN 1976)

On the other hand several radiologic reports indicate that minor lesions particularly in the colon but also in the small bowel may well be demonstrated provided special techniques are used (VANDENBROUCKE et coll 1964 SELLINK BRAHME & FORK 1976 ENGELHOLM & PEETERS ENGELHOLM et coll 1976 FRASER & FINDLAY

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well the patient gave no consent to repeat angiography Scintigraphy of the kidney 18 months after the embolization showed no function of the kidney the patient is still feeling well

SUMMARY

Percutaneous transcatheter arterial embolization was performed in a case of severe haemophilia A to control haemorrhage secondary to renal trauma The treatment proved to be life saving Eighteen months follow up revealed no evidence of hypertension renal failure or infection

ZUSAMMENFASSUNG

Eine perkutane Transkatheter Embolisierung der Nierenarterien wurde in einem Fall einer schweren Hämophilie A vorgenommen um eine Blutung als Folge eines renalen Traumas unter Kontrolle zu bringen Die Behandlung erwies sich als lebensrettend Nach 6 Monaten waren keine Zeichen einer Hypertension eines Nierenschadens oder einer Infektion vorhanden

RESUME

Les auteurs ont fait une embolisation arterielle par cathétérisme percutané dans un cas d hémophilie A grave pour arrêter une hémorragie secondaire à un traumatisme rénal Ce traitement a permis de sauver la vie du malade Une surveillance pendant 6 mois n a pas montré de signe d hypertension d insuffisance renale ou d infection

REFERENCES

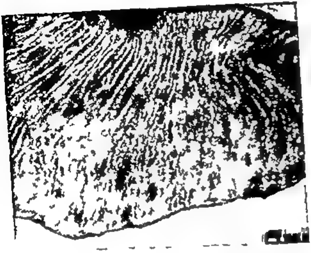
Bookstein J and Goldstein H M Successful management of postbiopsy arteriovenous fistula with selective arterial embolization Radiology 109 (1973) 535

Chuang V Reuter S R Walter J Foley W D and Bookstein J J Control of renal hemorrhage by selective arterial embolization Amer J Roentgenol 125 (1975) 300

Lucey D T Smith M J and Koontz W Jr Moderen trends in the management of urologic trauma J Urol 107 (1972) 641

Scott R Jr Carlton C E Ashmore A J and Duke H N Initial management of non penetrating renal injuries clinical review of 111 cases J Urol 90 (1963) 535

Silber S J Collins E and Clark R Treatment of hemorrhage from renal trauma by angiographic injection of clot J Urol 116 (1976) 15



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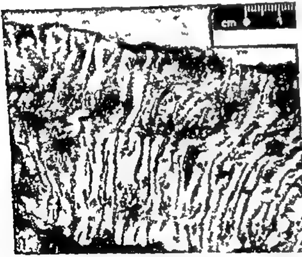

b

Fig 1 a) Ileum Multiple small superficial aphthoid lesions in the mucosa and edema The aphthoid lesions often on top of the folds of Kerckring b) Colon Multiple small aphthoid ulcers and a few punched out ulcers (↔) Confluence of small ulcers to larger longitudinal ulcers which seem to have a relation ship to the three colonic teniae (→)

Radiographs Small bowel examinations were mostly performed by the conventional follow through techniques but from 1972 the enteroclysis technique described by SELLINK was increasingly used

The double contrast method (WELIN 1962) was used for the colon examinations in all patients at this hospital Thirty three patients referred from other hospitals were as a rule examined by the conventional barium enema technique if necessary double contrast examinations were performed in these patients

1976 LAUFER & HAMILTON SIMPKINS 1976) However, no attempts have been made to *compare various techniques or to assess their accuracy*

Lesions demonstrated at radiography in a defined group of patients operated upon for Crohn s disease were compared with the findings at operation and those at microscopy of resected specimens Furthermore an attempt was made to assess the accuracy of the radiographic techniques used and to establish criteria for the radiologic diagnosis of Crohn s disease of the small and large bowels

Material and Methods

The material was derived from films and records of 195 consecutive patients *(92 males and 103 females)* in whom a primary operation for Crohn s disease was performed at Malmo Allmanna Sjukhus during a 15 year period 1959–1973 (BRAHME *et coll 1975) Residents of Malmo comprised 162 patients and 33 were referred from* other hospitals for clinical evaluation and surgical management About 90 per cent of the cases diagnosed in Malmo during this period are included The age of the patients at onset of the disease ranged from 10 to 79 years with a maximum of the age specific curve in the third decade

The series comprised only patients in whom radiography was performed before operation 19 patients operated upon immediately on admission being excluded Thus the material consisted of 385 large bowel and 309 small bowel examinations in *176 patients* For various reasons no *large bowel examination* was *performed* in 19 of these patients and in 4 no small bowel examination

In 75 per cent of the patients the small bowel was examined within 4 weeks before operation and in 80 per cent the colon In the remaining patients the interval was 1 month to 2 5 years (mean 6 months) for examination of the small bowel and 1 month to 1 year (mean 3 months) for examination of the colon During the later half of the series most examinations were performed within 1 to 3 weeks before surgery

The operative procedures were relatively uniform throughout the series Resection of intermediary segments of the colon and by pass operations were not performed Local resection of the distal ileum and the right hemicolon was performed when the disease was *supposed to involve the distal ileum or the* distal ileum and the right hemicolon (98 patients) When both the right and the left hemicolon were supposed to be involved the procedure was colectomy and ileostomy (63 patients) Three patients were operated upon with resection of the rectum and the aboral large bowel and in 7 patients the operative procedures differed from the general principles

At microscopy all cases were classified according to the criteria established by MORSON and accounted for by BRAHME et coll

With few exceptions (5 examinations in 3 patients) it was possible to review all films The radiographic appearance and the distribution of the lesions were recorded and the results were compared with the original radiographic reports the operative reports the results of microscopy and photographs of the excised specimens

Fig 4 Ileum Abnormalities characteristic of edema contour of bowel irregular and mucosal folds fused

with a Peyer s patch In the colon they are often multiple and may coalesce to longitudinal ulcers Larger ulcers (rounded longitudinal serpiginous) penetrate deep into the wall of the intestine resembling fissures Longitudinal and transverse ulcers together with intervening edematous mucosa create the well known cobble stone appearance Characteristically the ulcers are discontinuously distributed over the mucosa and separated by areas of edematous but otherwise unaffected mucosa

Fibrosis is a more prominent feature in later stages and may give rise to strictures The wall of the bowel and the mesentery are thickened and the mesentery contains varying amounts of enlarged lymph nodes

Distribution The jejunum and oral part of the ileum may be uniformly involved by superficial ulcers and edema but most often there is a segmental distribution of the lesions with multiple strictures in association with more severe ulceration

In the distal ileum the most aboral 10 to 50 cm are always continuously involved by disease This segment and more oral segments may be sharply demarcated but often no such demarcation is found The severity of the lesions decreases in the oral direction and aphthoid ulcers and other manifestations of disease may be found at varying distances from the aborally involved segment (Fig 3)

In the colon the macroscopic appearances vary more than in the distal ileum Severe ulceration and cobble stone formation are the most characteristic features but the presence of disease may be indicated by edema and superficial ulcers alone The discontinuous nature of the disease is more evident in the colon than in the distal ileum and areas without evident disease are frequently found In segments without mucosal ulceration the mucosa may appear grossly intact only patchy mucosal atrophy and fibrosis of the muscularis mucosae being present

More detailed information of the pathologic features of the disease may be ob

Fig 2 Ileum Isolated punched out ulcers in the mucosa Ulcers of this type are usually seen in connection with Peyer s lymphoid patches

Fig 3 Distal ileum Ulceration and characteristic thickening of the intestinal wall due to transmural inflammation Two isolated punched out ulcers oral to the main lesion

Survey of gross pathology The morphologic abnormalities that may be reflected in the films are complex and may be summarized as follows

Crohn s disease is a chronic granulomatous inflammatory process characterized macroscopically by edema ulceration and fibrosis and when fully developed is transmural The earliest abnormalities hyperplasia of lymphoid tissue and lymphedema occur in the submucosa

Aphthoid ulcers are early mucosal lesions occurring in the epithelium overlying lymphoid follicles or in association with foci of lymphocytic infiltration (Fig 1)

Shallow punched out ulcers 2 to 20 mm in diameter probably represent a growth of the aphthoid ulcers (Fig 2) In the small bowel they often develop in connection

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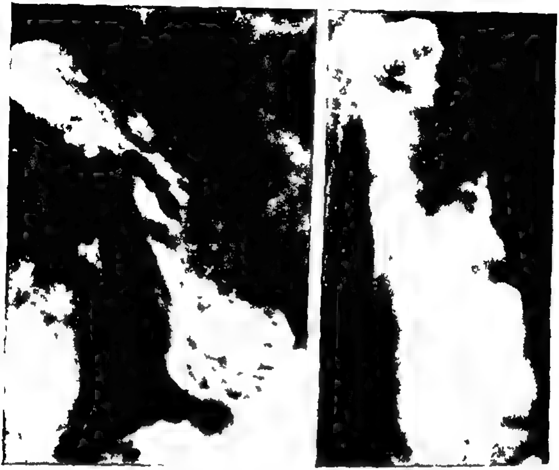

a b

Fig 5 Distal ileum a) Irregular longitudinal folds b) Broadened folds and absence of folds

tained from previous reports (WARREN & SOMMERS 1954 MORSON) In this connection only features of interest for the comparison between the morphology and the radiologic appearances are considered

Results

The radiographic manifestation of the disease largely reflected the gross pathology Thus the earliest abnormalities observed in the films were edema of the mucosa and the submucosa often accompanied by different types of superficial ulcers With progression of the disease larger ulcers and fibrosis were the main characteristics *However the radiographic appearance of individual lesions* varied between the small and the large bowel

Small bowel

Edema The mucosal folds were widened irregular and sometimes partly fused and the normal regular outline of the bowel was lost (Fig 4) In the distal ileum the

Fig 6

Fig 7

Fig 6 Distal ileum Multiple aphthoid ulcers
Fig 7 Distal ileum Superficial ulcers of different sizes (→) and longitudinal (↦)

edema could also appear as irregular longitudinal folds or total absence of folds (Fig 5)

Aphthoid ulcers appeared in the films as tiny specks of barium The e ulcers were ob erved only en face They could be multiple and located characteristically to the top of the mucosal folds or could appear isolated surrounded by a well-defined halo At microscopy this halo corresponded to a localized edema in association with an enlarged lymphoid follicle (Figs 6 7)

Larger ulcers could be observed both in profile and en face In the distal ileum characteristic longitudinal ulcers (Fig 7) together with transverse ulcers and intervening non ulcerated mucosa created the cobble stone appearance In oral the part of the small bowel large solitary ulcers were usually associated with a narrowing of the lumen

Fibrosis was usually excentric producing pseudodiverticula of the opposite wall but could also be concentric causing a more marked narrowing of the lumen As a certain degree of flexibility could be observed on fluoroscopy or be demonstrated by the enteroclysis technique most narrowings were considered to be due to spasm The wall of the bowel was only rarely completely rigid and if so the rigidity involved only a short segment

Thickening of the wall of the intestine and the mesentery appeared as rigidity and

Fig 8 Fig 9

Fig 8 Colon Edema Transverse streaks of barium contrast in the fully air distended colon Spiculated profile appearance

Fig 9 Aphthoid ulcers surrounded by a zone corresponding to edema and lymphoid hyperplasia

separation of individual loops and was also responsible for the characteristic deformation of the cecum

Fistulas developed between adjacent loops of the intestine to pelvic and abdominal viscera or to the abdominal wall Sometimes the intestinal loops seemed to surround a mass, which usually consisted of a conglomerate of enlarged lymph nodes or occasionally an abscess

Large bowel

As in the small bowel the earliest abnormalities were due to edema of the submucosa and the mucosa The radiographic changes corresponding to only a slight edema were often subtle and difficult to appraise In post evacuation films the normal mucosal pattern could be replaced by a nodular appearance or longitudinal rope like folds In a double contrast examination fine transverse streaks of barium could be observed en face in profile a slight irregularity of the outline of the bowel or a discreet saw tooth appearance (Fig 8) Similar abnormalities also occurred in patients in whom mucosal ulcerations had diminished or vanished and in the remaining

Fig 10

Fig 11

Fig 10 Colon Multiple punched-out ulcers in profile (→)

Fig 11 Colon Punched out ulcers coalescing to longitudinal ulcers (→)

colon in several cases of hemicolectomy A diagnosis of edema can only be made if the abnormalities are seen in the fully air distended colon and involve long segments

Contemporary with edema or somewhat later small aphthoid ulcers appeared These ulcers were only observed en face and had a similar appearance to those in the small bowel (Fig 9) They had a diameter of 1 to 2 mm and were scattered or arranged in groups In a few patients they were numerous and uniformly distributed covering the entire colonic mucosa and differentiation from ulcerative colitis was almost impossible However in most patients they were irregularly distributed along the length and the circumference of the intestine and separated by areas of non ulcerated mucosa

With progression of the disease punched out ulcerations frequently occurred They were 2 to 20 mm in diameter often surrounded by a halo When viewed en face these ulcers appeared characteristically as a ring of barium They were occasionally observed in profile and then appeared shallow and broad based sometimes with undermined edges (Fig 10) Like the aphthoid ulcers they were unevenly distributed

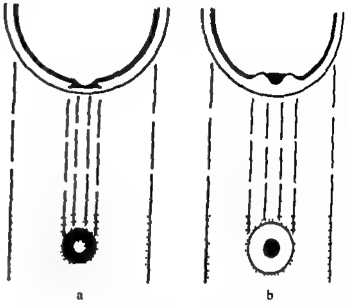

Fig 12 Anatomic and physical basis for the radiographic appearance of (a) punched out ulcers (b) aphthoid ulcers

but sometimes orientated along the teniae and could coalesce to form longitudinal ulcers (Fig 11)

The anatomic and physical basis for the radiographic appearance of aphthoid and punched out ulcers is illustrated in Fig 12 Both aphthoid and punched out ulcers were frequently found in all stages of the disease and in a small number of patients they dominated throughout the disease without tendency to grow to more severe ulcerations

Solitary nodular defects were most common at the lower border of the transverse colon often with a central deep ulceration (Fig 13) These lesions probably represented aggregates of enlarged lymphoid follicles and appeared in all stages of the disease They were transient findings and left behind a decreased flexibility of the wall of the intestine

In more advanced colonic disease ulcerations of various depth and appearance were unevenly distributed throughout the involved segments and confluence of ulcerations formed longitudinal and serpiginous ulcers of various lengths A typical cobble stone appearance was observed in about 25 per cent of patients with advanced disease It was usually very characteristic but could resemble the pseudo polyposis of ulcerative colitis

Characteristically the mucosal lesions had a patchy distribution with areas of non ulcerated mucosa separating the ulcerations (Figs 10 11)

A decreased flexibility usually of the lower border of the transverse colon or the medial border of the ascending and descending colon caused convergence of the haustral markings or in more advanced cases saccular dilatation of the contralateral border These abnormalities were caused by fibrosis which also caused single or multiple strictures In more advanced cases the fibrosis sometimes caused a more marked narrowing of the lumen and a shortening of the entire large bowel

Fig 13 Colon Solitary nodular defect Profile view with a deep central ulceration (→)

Fistulas were observed in the anal region but were otherwise less common in the colon than in the small bowel

In 20 patients a kissing lesion (SCHOFIELD 1965) was observed in the sigmoid colon This lesion was caused by encroachment of the colon by disease of the neighbouring distal ileum (Fig 14)

Medical treatment as a rule caused no characteristic alteration However in 2 patients treated with diversion by ileostomy and cortisone enemas the mucosa changed and assumed a very smooth granular appearance indistinguishable from ulcerative colitis

Accuracy of radiographic technique

The radiographic techniques used were considered as to their effectiveness in demonstrating different types of lesions in revealing the presence of disease and in revealing the extent of disease

Small bowel examination was performed in 172 patients The follow through technique was used exclusively in 160 patients the enteroclysis technique exclusively in 3 and 9 patients were examined by both techniques The films were compared with microscopic findings in 169 patients

Fig 14 Ileum (↔) with kissing lesion in the sigmoid colon (→)

The follow through technique revealed only gross abnormalities All 7 patients with widespread small bowel disease had symptoms long before a radiographic diagnosis could be made The presence of disease in the distal ileum was revealed in 142 of 146 patients while no radiographic diagnosis could be made in 4 The extent of disease could not be assessed in any of the patients

The enteroclysis technique gave more detailed information Aphthoid ulcers and slight submucosal edema could be demonstrated However these lesions were demonstrated with a varying degree of accuracy and the extent of disease could not be adequately assessed in any patient

Large bowel examination The double contrast examination was used in a total of 146 patients In 92 of 94 patients with colonic Crohn's disease the films were compared with the microscopic findings

Gross lesions were consistently demonstrated but minor lesions with a varying degree of accuracy depending on the technical quality of the examinations In those of good quality, a high degree of correspondence always existed between the radiographic and the macroscopic findings

The presence and extent of disease as compared with the findings in the resected specimens were adequately demonstrated in all 92 patients However considering the original reports of the radiographic examinations it was found that lesions involving long segments of the colon were overlooked in 28 patients In 14 of these patients the diseased segments were resected at operation but in the remaining 14 the lesions were left behind

Discussion

For many years the surgical management of Crohn's disease in most centers was largely conservative and directed mainly towards complications of the disease. Therefore a more refined radiologic diagnosis was not needed and radiography was mostly performed for the purpose of differential diagnosis. The gross radiographic features of the disease were well known and their presence was evident even to the less experienced radiologist. The morphologic basis for the abnormalities was also well recognized at operation. During the past 5 to 10 years the surgical attitude to the disease has changed in many centers. A trend towards earlier and more radical resectional procedures has appeared aiming at removal of macroscopically affected segments of the bowel (WALLENSTEN 1971). Consequently the demands on radiology have increased. The diagnosis of minor mucosal and submucosal lesions is now considered important. These lesions often indicate the macroscopic extent of the disease and they cannot be recognized at operation by external inspection or palpation.

The small bowel is the most difficult part of the gastrointestinal tract to explore at radiography. Macroscopically observed lesions in the resected specimens were not satisfactorily demonstrated by any of the techniques used. In accordance with the results of other authors (DYER & coll. 1970, OSBORN & FRIEDLAND 1973) the follow through technique revealed gross lesions only, while with the enteroclysis technique it was possible to make a diagnosis also of minor mucosal ulcers and of slight submucosal edema in the distal ileum (EKBERG 1977). However, due to the topographic anatomy of the small bowel, minor lesions in orally located segments were not satisfactorily demonstrated. Consequently the extent of disease in the small bowel could not be adequately assessed by either of the two techniques used.

In large bowel examination performed by the double contrast technique there was a high degree of correspondence between macroscopically observed lesions and the radiographic findings. The present results clearly indicate that in films of good technical quality it is always possible to make a radiographic diagnosis of even minute mucosal and submucosal lesions in the colon.

The explanation of the radiographic appearance of abnormalities compatible with slight edema in the mucosa and submucosa is still obscure. Probably it is produced by deepening and straightening of the shallow circumferential grooves (the innominate lines) that normally exist in the colonic mucosa. Due to the distension of the colon by air, these grooves normally are only faintly visible. However, when edema is present the mucosal ridges between the grooves are not flattened and barium is retained in the grooves. When the colon is not fully distended a similar appearance may occur also in the normal colon. According to WILLIAMS (1965) the innominate lines are visible in about 25 per cent of double contrast examinations though often only after careful search and often covering only a few centimeters. This is in agreement with the present experiences. MATSUURA et coll. (1977) stated

that, using a special technique, the innominate lines are demonstrable in about 90 per cent of the examinations Both WILLIAMS and MATSUURA et coll emphasized the normal nature of the innominate lines and furthermore MATSUURA et coll suggested that their absence is indicative of a pathologic process This is not consistent with our experience With the technique described by WELIN the innominate lines are not visible at all in about 75 per cent of all examinations If they are clearly demonstrated in detail and involve long segments of the colon it is a definite though non specific indicator of a pathologic condition such as colitis prolonged diarrhoea laxative abuse or evident edema Microscopy of excised specimens and biopsies from areas with visible innominate lines at radiography has shown that edema is present in the submucosa Consequently it seems plausible that the edema is responsible for the radiographic appearance

Aphthoid ulcers in the colon were overlooked in many patients, according to the original reports Probably they were considered to be artefacts However they have a characteristic appearance especially when they are surrounded by a halo and should cause no diagnostic difficulty

Ring shaped punched out ulcers were also originally overlooked in many patients In Crohn s disease they occurred in all stages of the disease and were most often numerous A similar type of ulcer may sometimes be observed in other types of colitis but are then occasional findings and few in number In ulcerative colitis the have less well defined margins and should cause no differential diagnostic difficulty The punched out ulcers should be considered characteristic of Crohn s disease

For many years various methods of radiography of the colon have been discussed The most widely used method seems to be the high kV barium enema Recently MARGULIS (1976) recommended this method for routine use and suggested that the double contrast examination should be used only as a supplementary method In a reply to this communication MILLER (1977) advocated the air contrast colon examination for patients with a high risk of colon malignancy He also added that there may be certain exceptions to the use of the air contrast technique and that the diagnosis of inflammatory bowel disease may be such an exception However, in the present series it was clearly proved that the assessment of the extent of disease in one third of the patients was largely dependent on the radiologic demonstration of superficial ulcers Aphthoid ulcers have not been reported when only barium enema is used Experiments in progress in this department clearly indicate that they are not demonstrable by this technique

It might be argued that the demonstration of these lesions lacks practical importance However the present results indicate that their demonstration has several advantageous consequences

(1) An earlier diagnosis of colitis is possible in many patients

(2) Colonoscopy will only have to be used in exceptional cases as even very delicate mucosal details will be demonstrated by a properly performed double contrast examination (FRASER & FINDLAY)

(3) The differentiation from other types of colitis is rendered more facile (LAUFER & HAMILTON) A proper evaluation of the discontinuous nature of the lesions in Crohn s disease is not possible by the barium enema technique and neither will aphthoid or punched out ulcers be demonstrated Consequently using the barium enema only the differential diagnosis between Crohn s disease and ulcerative colitis becomes more difficult a fact that is reflected by inter observer variations of about 25 per cent in most reported series (MARGULIS et coll 1971 NELSON et coll 1973 KIRSNER 1975)

(4) The extent of colonic disease can be adequately assessed Increasing experience indicates that excision of macroscopically involved segments of the bowel improves the prognosis both concerning postoperative complications and recurrence of the disease (WALLENSTEN)

Thus it is evident that the double contrast technique should be used routinely not only in the search for tumors but also in patients with evidence or clinical suggestion of colitis

SUMMARY

Preoperative films of 176 patients operated upon for Crohn s disease were reviewed and compared with microscopic findings in the resected specimens in order to assess the accuracy of the radiographic techniques used It was found that a diagnosis of the presence and the extent of the disease was often dependent on the demonstration of minor mucosal ulcers and less marked submucosal edema These lesions were not adequately demonstrated by any of the techniques used for small bowel examination but were consistently revealed by the double-contrast technique used for examination of the colon

ZUSAMMENFASSUNG

Die präoperativen Filme von 176 Patienten die wegen einer Crohns Erkrankung operiert worden waren wurden retrospektiv untersucht und mit den mikroskopischen Befunden in den resektierten Abschnitten verglichen um die Genauigkeit der verwendeten röntgenologischen Technik festzustellen Es wurde gefunden dass die Diagnose des Vorkommens und des Ausmasses der Erkrankung oftmals vom Nachweis von geringeren Ulcera der Mukosa und weniger ausgeprägten Submukosa Ödemen abhängig ist Diese Veränderungen werden durch keine der Techniken die für die Dünndarmuntersuchungen verwendet werden adäquat nachgewiesen werden jedoch stets bei der Doppelkontrast Technik die für die Untersuchung des Kolon verwendet wird festgestellt

RESUMÉ

Les radiographies pré opératoires de 176 malades operès de maladie de Crohn ont éte revues et comparées avec les resultats microscopiques des pièces operatoires pour évaluer la précision des techniques radiographiques utilisées Les auteurs ont constate que le diagnostic de la présence et de l etendue de cette affection dépend souvent de la mise en évidence de petites ulcérations muqueuses et d oedèmes sous muqueux moins marqués Ces

that, using a special technique the innominate lines are demonstrable in about 90 per cent of the examinations Both WILLIAMS and MATSUURA et coll emphasized the normal nature of the innominate lines and furthermore MATSUURA et coll suggested that their absence is indicative of a pathologic process This is not consistent with our experience With the technique described by WELIN the innominate lines are not visible at all in about 75 per cent of all examinations If they are clearly demonstrated in detail and involve long segments of the colon it is a definite though non specific indicator of a pathologic condition such as colitis prolonged diarrhoea laxative abuse or evident edema Microscopy of excised specimens and biopsies from areas with visible innominate lines at radiography has shown that edema is present in the submucosa Consequently it seems plausible that the edema is responsible for the radiographic appearance

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MATSUURA K NAKATA H TAKEDA N NAKATA N and SHIMODA Y Innominate lines of the colon Radiology 123 (1977) 581
MEUWISSEN S KATOLINA S PAPE D AGENANT D OUSHOORN H H and TYTGAT G N J Crohn s disease of the colon Analysis of the diagnostic value of radiology endoscopy and histology Dig Dis 21 (1976) 81
MILLER R E The barium enema in the high risk carcinoma patient Radiology 123 (1977) 813
MORSON B C Pathology of Crohn s disease Clin Gastroent 1 (1972) 265
NELSON J A MARGULIS A R GOLDBERG H I and LAWSON T L Granulomatous colitis significance of involvement of the terminal ileum Gastroenterology 64 (1973) 1071
OSBORN A and FRIEDLAND G A radiological approach to the diagnosis of small bowel disease Clin Radiol 24 (1973) 281
SCHOFIELD P F The natural history and treatment of Crohn s disease Ann roy Coll Surg Engl 36 (1965) 258
SELLINK I L Examination of the small bowel by means of duodenal intubation H E Stenfert Kroese Leiden 1971
— Radiologic examination of the small intestine by duodenal intubation Acta radiol Diagnosis 15 (1974) 318
SIMPKINS K C Some aspects of the radiology of Crohn s disease Brit J Surg 59 (1972) 810
— The barium enema in Crohn s colitis *In* The management of Crohn s disease p 63 Edited by I T Weterman A S Pena and C C Booth Excerpta Medica Amsterdam 1976
STANLEY P KELSEY FRY I DAWSON A M and DYER N Radiological signs of ulcerative colitis and Crohn s disease of the colon Clin Radiol 22 (1971) 434
VAN DEN BROUCKE J BODART P DIVE C LENS E et VAN TRAPPEN G L ileo-colite granulomateuse Etude clinique et radiologique *In* Actes VII Congrès International de Gastro Entérologie Vol 1 p 451 Bruxelles 1964
VAN TRAPPEN G A prospective study of colonoscopy in Crohn s disease *In* The management of Crohn s disease p 79 Edited by I T Weterman A S Pena and C C Booth Excerpta Medica Amsterdam 1976
WALLENSTEN S Results of surgical treatment in Sweden *In* Regional enteritis (Crohn s disease) Skandia International Symposia p 177 Edited by A Engel and T Larsson Nordiska Bokhandelns Forlag Stockholm 1971
WARREN S and SOMMERS S C Pathology of regional enteritis and ulcerative colitis J Amer med Ass 154 (1954) 189
WELIN S Über die rontgenologische Untersuchung des Dickdarmes mit der Doppelkontrast methode Die Malmotechnik Radiologe 2 (1962) 87
WILLIAMS I Innominate grooves in the surface of the mucosa Radiology 84 (1965) 877
WILLIAMS J A Surgery and the management of Crohn s disease Clin Gastroent 1 (1972) 469

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REFERENCES

ATWELL J D DUTHIE H L and GOLIGHER J C The outcome of Crohn s disease Brit J Surg 52 (1965) 966

BRAHME F Roentgenology *In* Regional enteritis (Crohn s disease) Skandia International Symposia p 81 Edited by A Engel and T Larsson Nordiska Bokhandelns Forlag Stockholm 1971

— and FORK T Roentgenology of the colon in Crohn s disease Air contrast studies of the lesions and their development Radiologe 16 (1976) 489

— LINDSTRÖM C and WENCKERT A Crohn s disease in a defined population An epidemiologic study of incidence prevalence mortality and secular trends in the city of Malmo Sweden Gastroenterology 69 (1975) 342

DYER N H RUTHERFORD C VISICK J H and DAWSON A M The incidence and reliability of individual radiographic signs in the small intestine in Crohn s disease Brit J Radiol 43 (1970) 401

EKBERG O Crohn s disease of the small bowel examined by double contrast technique A comparison with oral technique Gastrointest Radiol 1 (1977) 355

ENGELHOLM L and PEETERS J P Radiology in granulomatous colitis *In* The management of Crohn s disease p 57 Edited by I T Weterman A S Pena and C C Booth Excerpta Medica Amsterdam 1976

— MAINGUET P and POTVLIEGE P Radiology in early Crohn s disease *In* The management of Crohn s disease p 73 Edited by I T Weterman A S Pena and C C Booth Excerpta Medica Amsterdam 1976

FRASER G M and FINDLAY J M The double contrast enema in ulcerative colitis and Crohn s colitis Clin Radiol 27 (1976) 103

KANTOR J L Regional (terminal) ileitis Its roentgen diagnosis J Amer med Ass 103 (1934) 2016

KEMP HARPER R A The radiological spectrum of Crohn s disease Proc roy Soc Med 64 (1971) 1181

KIRSNER J B Problems in the differentiation of ulcerative colitis and Crohn s disease of the colon The need for repeated diagnostic evaluation Gastroenterology 68 (1975) 187

LAUFER I and HAMILTON J The radiological differentiation between ulcerative and granulomatous colitis by double contrast radiology Amer J Gastroenterol 66 (1976) 259

MARGULIS A R Is double-contrast examination of the colon the only acceptable radiographic examination? Radiology 119 (1976) 741

— GOLDBERG H I LAWSON T L MONTGOMERY C K RAMBO O N NOONAN C D and AMBERG J R The overlapping spectrum of ulcerative and granulomatous colitis A roentgenographic pathologic study Amer J Roentgenol 113 (1971) 325

MARSHAK R H Granulomatous disease of the intestinal tract (Chron s disease) Radiology 114 (1975) 3

— and LINDNER A E Granulomatous colitis and ileo colitis with emphasis on the radiologic features Progr Gastroent 1 (1970) 357

— and WOLF B S Roentgen findings in regional enteritis Amer J Roentgenol 76 (1955) 1000

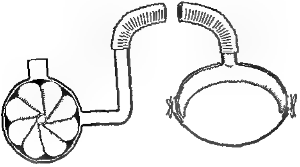

Fig 1 Equipment for application of abdominal compression Electric fan and rubber balloon (23 cm × 50 cm) with encircling bandage (25 cm wide)

SANDMARK (1963 a) showed that the discrepancy between results of radiography and other methods may partly be due to the fact that the density of barium meals is considerably higher than that of normal gastric contents Contrast media have therefore been prepared to be isodense with water (1 0 g/cm³)

The aim of the following investigation was to make use of such a contrast medium—polyiodostyrene (HAGSTAM & SANDMARK to be published)—in an attempt to evaluate a technique for the demonstration of pathologic gastro oesophageal reflux easily reproducible and to ascertain what mechanism constitutes the most important means of protection against reflux

Method

The easiest way to provoke gastro oesophageal reflux and hiatal herniation is to increase the intra abdominal pressure so that a pressure gradient across the diaphragm is obtained A normal deep inspiration may produce a difference in pressure of about 10 kPa (75 mmHg) between the abdominal and thoracic cavities

A square rubber balloon (23 cm × 50 cm) with an encircling bandage (25 cm wide) was fixed over the patient s abdomen in order to obtain increased intra abdominal pressure in a constant reproducible way The rubber balloon was connected to an electric fan (Fig 1) which at constant speed maintains a constant pressure in the balloon irrespective of the volume of the balloon By varying the speed of the fan the pressure in the balloon varied to a maximum of 7 3 kPa (55 mmHg) corresponding to a maximum increase in intra abdominal pressure of 2 7 kPa (20 mmHg)

The contrast medium used P contrast (research preparation manufactured by Ferring Pharmaceuticals Malmo Sweden) consists of spherical particles of poly iodostyrene comprising homogeneously dispersed closed air containing cells The product contains about 50 per cent of iodine chemically bound The particle diameter ranges from 0 2 to 0 5 mm and the density is 0 90 to 1 10 The particles are not resorbed and the density is not altered during the passage through the gastro intestinal tract The particles are dispersed in a low viscosity diluent (0 25 % Keltrol solution) Each examination requires 25 to 30 g P-contrast dispersed in about 150 ml diluent The patients were examined in the supine horizontal position with the

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HIATAL INCOMPETENCE AND GASTRO-OESOPHAGEAL REFLUX

D LINDELL and S SANDMARK

A normally efficient clamping mechanism between the stomach and the oesophagus prevents backflow of gastric contents into the oesophagus Considerable difference of opinion exists as to the anatomic and functional basis of this mechanism (INGELFINGER 1958 EDWARDS 1961 1973) The presence of a sphincter in the lower part of the oesophagus has been inferred from intraluminal pressure measurements and there is a widespread conception that such a sphincter constitutes the most important protection against reflux irrespective of whether the location is in the hiatal channel or—as in the case of a sliding hernia—in the thoracic cavity (COHEN & HARRIS 1972) However, there is also conflicting evidence an operation for hiatal hernia with reposition of the stomach into the abdomen and with constriction of the hiatal channel can obviate a reflux previously existing without implying any change in the condition of the lower oesophageal sphincter It therefore seems reasonable to consider whether a normal oesophageal hiatus does not in itself constitute an important means of protection against gastro oesophageal reflux

Numerous methods are available for demonstrating gastro oesophageal reflux, most of them inadequate Reflux of a conventional barium meal (density between 1 4 and 1 8 g/cm³) often correlates poorly with results from other clinical methods BENNETT (1973) considered that the radiological assessment of reflux is subject to so many vagaries of behaviour by both patient and radiologist as to be meaningless

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Table 2

Radiography compared with oesophagoscopy

	No of cases	Oesophagitis	Stricture
No herniation	23	0	0
Minor herniation	126	61	20
Major herniation	42	26	11
Total	191	87	31

Table 3

Radiography compared with oesophagoscopy

	No of cases	Oesophagitis	Stricture
Competent hiatus			
No herniation	23	0	0
Minor herniation	54	9	3
Major herniation	3	1	0
Total	80	10	3
Incompetent hiatus – no oesophageal reflux			
Minor herniation	10	4	2
Major herniation	17	6	3
Total	27	10	5
Incompetent hiatus + oesophageal reflux			
Minor herniation	62	48	15
Major herniation	22	19	8
Total	84	67	23

Intraluminal pressure measurement in the oesophagus was carried out in every case. After the patient had drunk about 200 ml of water the intra abdominal pressure was increased in the same way as during radiography, and the intra luminal pressure was recorded simultaneously at three levels (SANDMARK 1963 b).

Material

During the years 1973–1977 radiography with P-contrast was carried out on 191 patients with symptoms of gastro-oesophageal reflux. Age and sex distribution is given in Fig. 2. None of the patients had undergone surgery of the stomach or oesophagus. Conventional radiography with barium had demonstrated that most of them had a hiatal herniation.

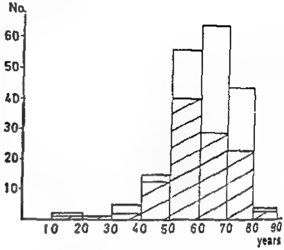

Fig 2 Age and sex distribution of the 191 patients (females = hatched columns)

right side turned slightly upwards About 100 ml of P contrast was ingested and by TV fluoroscopy the following factors were assessed (1) The propulsive peristalsis and its ability to empty the oesophagus from contrast medium (2) After the intra abdominal pressure was increased the patients ingested the remaining amount of P contrast and the ability of the peristalsis to empty the oesophagus from medium was evaluated (3) The presence of hiatal herniation assessed

The criterion for a minor herniation is the location of the sphincter and the mucosal junction at least 1 cm above the hiatus (cf WOLF 1970) The criterion for a major herniation is a diameter of more than 5 cm

The pressure was then relieved and if necessary the examination couch raised for emptying the oesophagus and a herniation The pressure was then increased again in order to note (4) transport of contrast medium up through the hiatus to a herniated part of the stomach and (5) reflux of contrast medium into the oesophagus

Supplementary examinations Oesophagoscopy was carried out on all patients mostly with a straight and rigid oesophagoscope under general anaesthesia but in some cases with a flexible fibre oesophagoscope (Olympus) under local anaesthesia Biopsies were taken when necessary

Table 1

Findings at oesophagoscopy

Oesophagoscopy	No of cases	Fibrous stricture
No oesophagitis	104	2
Slight oesophagitis (redness oedema)	30	5
Severe oesophagitis (ulceration fibrin coating bleeding)	57	24
Total	191	31

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Results

The findings at oesophagoscopy and radiography with P contrast at raised intra abdominal pressure appear in Tables 1, 2 and 3

Of the 10 patients with a competent hiatus (Table 3) and oesophagitis 3 had severe *oesophagitis one had mycosis (microscopically confirmed)* one was a grave alcoholic and one had a major herniation with only a weak peristalsis in the oesophagus 7 had only *slight oesophagitis*

Hiatal incompetence and gastro oesophageal reflux were present in various degrees In some cases the contrast medium trickled through the hiatus and occasionally up into the oesophagus whereas in other cases retrograde passage of the hiatus was instant and massive, straight up into the oesophagus without initial filling up of a hiatal herniation The latter occurred most often in connection with a minor hiatal herniation

Various degrees of peristalsis in the oesophagus were recorded In some cases the propulsion was strong enough to empty the oesophagus despite increased intra abdominal pressure but in other cases the oesophagus was not emptied even when the pressure was normal

Abnormalities indicating oesophagitis were most severe *in patients with an in* competent hiatus and an oesophagus with poor drainage power

The results of the intraluminal pressure measurements are in this context only briefly reported In the majority of patients it was possible to locate the lower oe sophageal sphincter (high pressure zone) above the hiatus (pressure inversion point) suggesting hiatal herniation With raised intra abdominal pressure it was possible in most patients with herniation to record increased pressure within a segment above the hiatus at least 2 cm in length—suggesting hiatal incompetence or gastro oesophageal reflux

With regard to the presence of hiatal herniation the results of radiography *with P* contrast agreed well with pressure measurements In some patients with pressure changes indicating hiatal incompetence and gastro oesophageal reflux on the other hand radiography showed a hiatal herniation but no incompetence

With regard to oesophagitis as demonstrated at oesophagoscopy correlation with hiatal incompetence was better as indicated by radiography than by intraluminal pressure measurement No complete correlation was found between oesophagitis at oesophagoscopy and pressure at rest in the lower oesophageal sphincter

Discussion

Normally *the* oesophagus passes through the hiatus and the transition to the stomach is in the abdominal cavity If the pressure in the abdominal cavity is higher than that in the thoracic cavity the stomach is pressed up against the hiatal channel and sometimes partly through it VESTBY & AAKHUS (1966) reported that radio

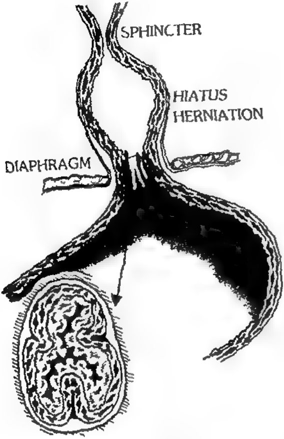

Fig 3 Competent hiatus The folds of the mucous membrane in the stomach are compressed and gastric contents cannot pass up into a herniated part of the stomach

graphy invariably demonstrates parts of the stomach above the hiatus if the intra abdominal pressure is sufficiently increased Different methods of radiography are associated with considerably varying pressure differences between the thoracic and abdominal cavities It can be very difficult to decide whether or not a pathologic sliding hernia is present The present standardized method of increasing the pressure maintains the pressure difference between the thoracic and abdominal cavities more or less constant from patient to patient and from examination to examination improving the diagnostic accuracy of hiatal herniation

The presence of gastro oesophageal reflux is of clinical significance The stomach is wider than the oesophagus When with increased intra abdominal pressure the stomach is press d up towards and possibly into the thoracic cavity the part that passes through the hiatal channel is compressed which may prevent the retrograde passage of gastric contents In principle this constitutes a valve mechanism in the hiatus competent (Fig 3) or incompetent (Fig 4) With the presence of gastro oesophageal reflux gastric contents can also be forced through the lower oesophageal

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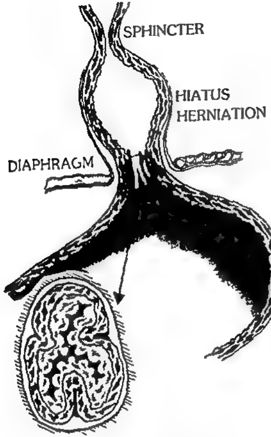

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amount of gastric contents can be pressed up into a large herniation without the sphincter pressure being exceeded

Oesophagitis was uncommon with a competent hiatus more common with an incompetent hiatus without reflux, and most common when the hiatus was incompetent with reflux In no case was reflux present without herniation

The hiatal mechanism appears at least as important a contribution to the protection against reflux as does the lower oesophageal sphincter

A further factor to be taken into consideration in the analysis of reflux oesophagitis is the drainage power of the oesophagus The most severe oesophagitis was found in patients with a poor propulsive peristaltic power

The density (weight per unit volume) of the contrast medium is important in the demonstration of hiatal incompetence and gastro oesophageal reflux The radiographic method described employing barium sulphate or gastrographin as contrast agent is less adequate in demonstrating hiatal incompetence and gastro oesophageal reflux in patients with oesophagitis at oesophagoscopy and gastro oesophageal reflux at intraluminal pressure and pH measurements (SANDMARK 1963 a) This gave rise to the preparation of contrast media with the same density (1 0 g/cm³) as ordinary gastric contents In order to maintain this density the contrast media must have a relatively high viscosity Developmental forms of such media have been employed in more than 200 patients who had hiatal herniation with or without oesophagitis Even in the case of patients with severe oesophagitis it was very difficult to demonstrate hiatal incompetence The plugging of the hiatal channel was too efficient and considered to be an effect of the high viscosity of the contrast media This observation led to the development of a viscous preparation (Gaviscon) for the treatment of reflux oesophagitis (SANDMARK & ZENK 1964)

P contrast constitutes a medium with relatively low viscosity (100–200 cps) and with a density of 1 0 g/cm³ The fact that it has the same density as ordinary gastric contents means that gastro oesophageal reflux can be demonstrated with the patient in any position (even standing) When heavy barium sulphate is used the patient has to be positioned in such a way (with head lowered) that the barium suspension can be poured into the hiatal channel this constitutes a source of error inasmuch as the heavy medium itself exerts some pressure on the hiatal channel

In order to provide the clinician with adequate information in the case of possible reflux oesophagitis the radiographic examination should demonstrate whether (1) a hiatal herniation is present (2) the hiatal mechanism is competent or incompetent (3) the sphincter is capable of preventing reflux in the case of hiatal incompetence and (4) the peristalsis is adequate enough to drain the oesophagus

Examinations with P contrast can be carried out quickly and the results correlate well with the patients symptoms and with results obtained by other clinical methods Many years of experience with various radiographic contrast media show that pathologic hiatal incompetence and gastro oesophageal reflux can be demonstrated with greater accuracy by use of P contrast than by any other contrast medium

SUMMARY

Gastro-oesophageal reflux and hiatal incompetence were analysed in 191 patients using a new radiographic contrast medium polyiodostyrene with the same density (1 0 g/cm³) as ordinary gastric contents and correlated with supplementary oesophagoscopy and intra luminal pressure measurements A normal hiatus seems to be an important protection against gastro oesophageal reflux An incompetent hiatus involves a real risk for oesophagitis A low density low viscosity contrast medium improves the roentgenologic diagnosis of gastro oesophageal reflux

ZUSAMMENFASSUNG

Bei 191 Patienten wurde der gastro-osophageale Reflux und die Hiatus Schwache unter Verwendung eines neuen rontgenologischen Kontrastmittels Polyiodostyren mit der gleichen Dichte (1 0 g/cm³) wie der gewohnliche Mageninhalt untersucht und mit den osophagoskopischen Befunden und intraluminalen Druckmessungen korreliert Ein normaler Hiatus scheint ein wesentlicher Schutz gegen gastro-osophagalem Reflux zu sein *Ein in*suffizienter Hiatus bedeutet ein wirkliches Risiko fur eine O ophagitis Ein Kontrastmittel von niedriger Densitat und niedriger Viskositat verbessert die rontgenologische Diagnostik eines gastro osophagealen Refluxes

RESUMÉ

Le reflux gastro œsophagien et l insuffisance hiatale ont été etudies chez 191 malades grace a un nouveau moyen de contraste radiographique le polyiodostyrène qui a la meme densité (1 0 g/cm) que le contenu gastrique ordinaire *les resultats* ont ete correles avec une œsophagoscopie complementaire et une mesure de la pression intraluminale Un hiatus normal parait etre une protection importante contre le reflux gastro œsophagien Un hiatus insuffisant comporte un réel risque d œsophagite Un moyen de contraste de faible densite et de faible viscosite ameliore le diagnostic radiologique du reflux gastro-œsophagien

REFERENCES

BENNETT J R Symposium on gastro-oesophageal reflux and its complications The physician s problem Gut 14 (1973) 246

COHEN S and HARRIS L D The lower esophageal sphincter Gastroenterology 63 (1972) 1066

EDWARDS D A W The mechanism at *the cardia* The antireflux mechanism manometric and radiological studies Brit J Radiol 34 (1961) 474

— Symposium on gastro oesophageal reflux and its complications Definitions the anti reflux mechanism and symptoms Gut 14 (1973) 233

HAGSTAM H and SANDMARK S Polyiodostyrene Light weight contrast medium for functional examination of the gastrointestinal tract To be published in Acta radiol Diagnosis

INGELFINGER F J Esophageal motility Physiol Rev 38 (1958) 533

SANDMARK S (a) *Hiatal* incompetence Acta radiol (1963) Suppl No 219

— (b) Intraluminal pressures and pH in hiatus hernia and gastro-oesophagea reflux Acta oto-laryng 56 (1963) 683

— and ZENK L Treatment with Gaviscon in hiatus hernia (In Swedish) Svenska Lak Tidn 61 (1964) 1940

VESTBY G W og AAKHUS T Hyppigheten av hiatushernier (In Norwegian) Nord Med 75 (1966) 110

WOLF B S The inferior esophageal sphincter Anatomic roentgenologic and manometric correlation contradictions and terminology Amer J Roentgenol 110 (1970) 260

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ADRENAL ANGIOGRAPHY IN SIPPLE S SYNDROME

L EKELUND and J HOEVELS

Medullary carcinoma of the thyroid may be associated with other tumors The most frequently reported is pheochromocytoma (SIPPLE 1961) commonly occurring in a familial association When pheochromocytoma occurs in affected family members it is bilateral in two thirds of the cases (LJUNGBERG 1972) Even if more than 700 patients in multiple families have been recognized since 1961 angiographic documentation of the pheochromocytomas is rare Therefore it was considered motivated to report adrenal angiography in 8 patients with Sipple s syndrome

Material and Methods

The material comprised 8 patients 3 females and 5 males aged between 29 and 59 years All patients had medullary carcinoma of the thyroid Six of the patients had relatives with Sipple s syndrome while no familial association could be traced in 2 Five of the patients were normotensive while 3 had elevated blood pressures All of the patients had laboratory evidence of pheochromocytoma (elevated urinary vanillyl mandelic acid)

Abdominal aortography was performed in all patients and additional bilateral adrenal angiography in 6 Bilateral suprarenal phlebography was performed in 4 patients and unilateral phlebography in further 2 All cases but one were confirmed by surgery and subsequent microscopy All patients had adrenergic blockade with phenoxybenzamine before the angiography No complication were encountered

Submitted for publication 18 September 1978

Table

Summary of findings in 8 patients with Sipple s syndrome The urinary vanillyl mandelic acid was elevated in all cases

Case No	Age and sex	Famil assoc	Hyper tension	Angiography	Phlebo-graphy	Surgery	Microscopy
1	51 F	+	–	3 × 4 cm hypervasc mass L adrenal (asynchron)	—	R adrenal ectomy 1966 L adrenal ectomy 1976	Bilateral pheochro-mocytomas
2	48 M	–	–	6 × 7 cm moderately vasc mass R 5 × 4 5 cm hypovasc mass L Hepatic metastases (med thyroid ca)	L displace ment of veins	Bilateral adrenal ectomy	Bilateral pheochro-mocytomas
3	34 M	+	+	Enlarged hypervasc L adrenal 5 mm hypervasc lesion in normal sized R adrenal	Enlarged L adrenal Normal R	Bilateral adrenal ectomy	Bilateral medullary hyperplasia
4	59 M	+	–	Bilateral hypervasc lesions	Irregular veins L Displace ment R	Not operated upon	—
5	53 F	–	+	Bilateral hypovasc masses (asynchron)	L displace ment	R adrenal ectomy 1970 L adrenal ectomy 1971	Bilateral pheochro-mocytomas
6	29 M	+	–	3 5 × 2 cm hypervasc lesion L adrenal Normal R	L displace ment R normal	L adrenal ectomy	Pheochro-mocytoma
7	54 F	+	+	Large calcified mode rately vasc mass L adrenal	—	L adrenal ectomy	Pheochro-mocytoma
8	41 M	+	–	5 cm moderately vasc mass L adrenal Normal R	L displace ment & irregular veins R normal	L adrenal ectomy	Pheochro-mocytoma

Results

A summary of the clinical and angiographic findings is given in the Table

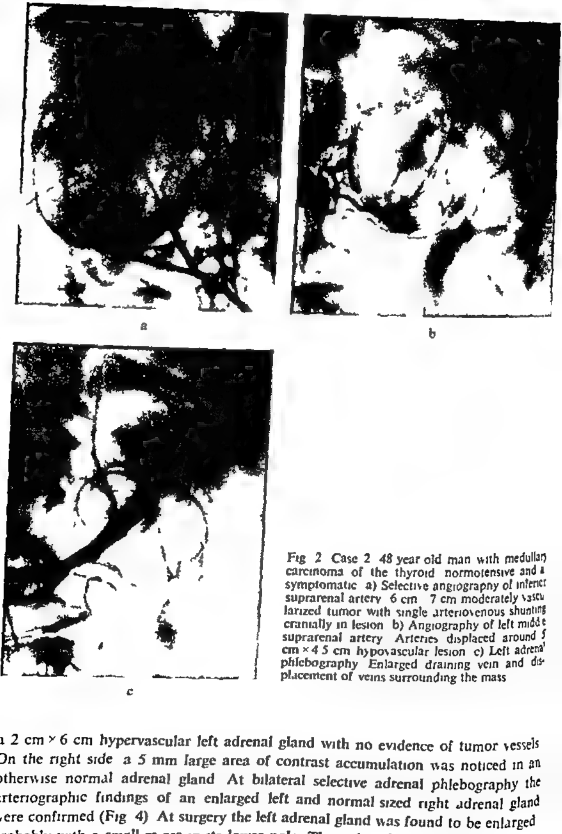
Bilateral lesions were found in 5 patients in 3 diagnosed simultaneously and in the other 2 with one and 10 years interval respectively One 51 year old woman

Fig 1 Case 1 51 year-old woman previously operated upon because of medullary carcinoma of the thyroid and right pheochromocytoma Selective angiography of left middle suprarenal artery 3 cm 4 cm hypervascular adrenal mass

(Case 1) with Sipple relatives was previously operated upon because of medullary carcinoma of the thyroid and right pheochromocytoma (hypervascular at angiography) She now complained of attacks of tachycardia and had laboratory evidence of a recurring pheochromocytoma Angiography including selective catheterization of the left middle suprarenal artery disclosed a 3 cm × 4 cm large hypervascular adrenal mass which was removed and proved to be a pheochromocytoma (Fig 1)

Elevated urinary vanillyl mandelic acid was found in a 48 year old man (Case 2) with medullary carcinoma of the thyroid but without known familial association of Sipple s syndrome He was normotensive and asymptomatic Abdominal aortography and bilateral selective adrenal angiography revealed bilateral adrenal tumors (Fig 2) Bilateral adrenalectomy was performed and microscopy demonstrated bilateral pheochromocytomas At surgery liver masses probably metastases were palpated At postoperative hepatic angiography multiple hypervascular liver metastases were demonstrated (Fig 3) Biopsy demonstrated these to be secondary to the medullary thyroid carcinoma

One 34-year-old male (Case 3) from a Sipple family was found to be hypertensive with attacks of tachycardia and sweatening His urinary vanillyl mandelic acid was elevated Abdominal aortography and bilateral selective adrenal angiography showed



a b c

Fig 2 Case 2 48 year old man with medullary carcinoma of the thyroid normotensive and asymptomatic a) Selective angiograpny of inferior suprarenal artery 6 cm 7 cm moderately vascularized tumor with single arteriovenous shunting cranially in lesion b) Angiography of left middle suprarenal artery Arteries displaced around 5 cm × 4 5 cm hypovascular lesion c) Left adrenal phlebography Enlarged draining vein and displacement of veins surrounding the mass

a 2 cm × 6 cm hypervascular left adrenal gland with no evidence of tumor vessels On the right side a 5 mm large area of contrast accumulation was noticed in an otherwise normal adrenal gland At bilateral selective adrenal phlebography the arteriographic findings of an enlarged left and normal sized right adrenal gland were confirmed (Fig 4) At surgery the left adrenal gland was found to be enlarged probably with a small m ass in its lower pole The right adrenal gland was macro

Fig 3 Case 2 Hepatic angiography demonstrating multiple hypervascular metastases secondary to medullary carcinoma of the thyroid

scopically normal Bilateral adrenalectomy was performed and microscopy demonstrated bilateral medullary hyperplasia

Concurrent bilateral adrenal tumors were also found in a 59 year old man from a Sipple family (Case 4) He was asymptomatic with elevated urinary vanillyl mandelic acid Angiography including bilateral selective suprarenal artery injections demonstrated hypervascular lesions on both sides Bilateral adrenal phlebography was also performed demonstrating an enlarged gland with irregular veins on the left side and venous displacement on the right (Fig 5) This patient did not accept surgical treatment as he was completely asymptomatic

In one 29 year old male (Case 6) from a Sipple family an asymptomatic medullary carcinoma of the thyroid was removed He was normotensive but elevated urinary vanillyl mandelic acid was present Therefore abdominal aortography and bilateral adrenal angiography were performed and a 3 5 cm × 2 cm hypervascular lesion was demonstrated in the left adrenal gland (Fig 6) No abnormality could be demonstrated within the right andrenal gland Bilateral adrenal phlebography was also performed The veins on the left side were displaced normal conditions were found on the right side The left adrenal gland was removed and found to harbour 2 pheochromocytomas in close connection with a diameter of 2 5 cm and 1 5 cm respectively

One 54-year old hypertensive woman (Case 7) had 6 years previously been operated upon because of medullary carcinoma of the thyroid She had a daughter with a pheochromocytoma At clinical examination a mass was palpated in the left side of the abdomen Urinary vanillyl mandelic acid was elevated At urography a large calcified mass was found to displace the left kidney caudally Abdominal aortography was performed and the large tumor was found to be moderately vascularized from

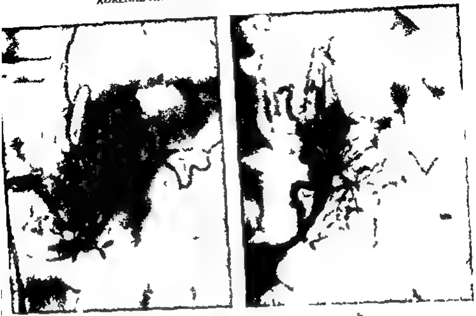
a b

c

Fig 4 Case 3 34 year old man with bilateral adrenal medullary hyperplasia a) Selective catheterization of left middle suprarenal artery Enlarged hypervascular adrenal gland without tumor vessels b) Left adrenal phlebography Normal venous appearance in enlarged gland c) Inferior suprarenal artery originating from supplementary artery to superior pole of right kidney 5 mm lesion accumulating contrast medium in normal sized adrenal gland

widened suprarenal arteries At subsequent surgery a huge pheochromocytoma was removed

In regard to the vascularity of the present pheochromocytomas one of the 2 patients with concurrent bilateral tumors had fairly well vascularized lesions (Case 4) while the other one had one moderately vascularized lesion and one hypovascular



a b

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Fig 5 Case 4 59 year old asymptomatic man from a Sipple family a) Selective angiography of left middle suprarenal artery Hypervascular lesion in left adrenal gland b) Left adrenal phlebography Tortuous and irregular veins in enlarged gland c) Angiography of right middle suprarenal artery demonstrating 2 5 cm larg hypervascular lesion

tumor (Case 2) In Case 3 with bilateral adrenal medullary hyperplasia angiography demonstrated a hypervascular enlarged adrenal gland on the left side without evidence of neova cularity and a small hypervascular nodule on the contralateral side In one of the 2 patients with asynchronous bilateral pheochromocytomas (Case 1) both

Fig 8 Case 6 29 year old man with medullary carcinoma of the thyroid Selective left middle suprarenal angiography 3 5 cm × 2 cm hypervascular adrenal tumor

tumors were hypervascular while in Case 5 both pheochromocytomas were hypovascular as estimated at angiography One of 3 patients with unilateral pheochromocytoma had a hypervascular tumor while the remaining 2 had moderately vascularized ones When comparing the various angiographic appearances among the present 8 cases it was not possible to find any characteristic or typical features which are also valid for the phlebographic findings

Discussion

In 1961 SIPPLE made the original association of medullary thyroid carcinoma and pheochromocytoma based on 6 cases The following statements from KEISER et coll (1973) may be cited Sipple s syndrome is medullary carcinoma of the thyroid pheochromocytoma and parathyroid disease It is transmitted as an autosomal dominant trait with a high degree of penetrance Medullary carcinoma of the thyroid can be accurately diagnosed early by measuring serum calcitonin often when all other diagnostic tests are negative The pheochromocytomas are similar to those occurring sporadically except that they are more often bilateral and often unresponsive to provocative tests Parathyroid hyperplasia is a definite part of the syndrome although often physiologically inconsequential and therefore diagnosed only at surgery for the thyroid carcinoma Recent biochemical findings support the hypothesis that the diverse features of Sipple s syndrome are caused by a dysplasia of

ieural crest cells The reported high incidence of bilateral pheochromocytomas is in good agreement with the present findings 5 of 8 patients having bilateral lesions

Numerous reports of the angiographic appearance of pheochromocytomas have appeared Considerable variation in vascularity has been indicated (FRY et coll 1967 LANNER & ROSENCRANTZ 1970 SUTTON 1975) as well as a high incidence of hypovascular pheochromocytomas (ZELCH et coll 1974) Partial infarction of adrenal pheochromocytomas may be one reason for them not being demonstrated at angiography (BALTAXE et coll 1973) Recently the angiographic findings in 34 patients with adrenal lesions were reviewed (HOEVELS & EKELUND 1979) including 9 pheochromocytomas and it was concluded that differential diagnostic difficulties certainly exist in distinguishing between various adrenal masses Neither could any specific angiographic characteristics be traced in the present material of adrenal masses On the other hand none of the present 8 cases with Sipple s syndrome presented with an angiographically avascular lesion and it might be that pheochromocytomas associated with this particular entity have a tendency to be more vascular than sporadically appearing ones

All the present lesions were detected from the arterial side and no further significant diagnostic information was obtained from adrenal phlebography per se This fact appears to indicate that the patient with medullary carcinoma of the thyroid and possible adrenal pheochromocytoma should first be examined by angiography including abdominal aortography and if possible selective adrenal angiography This is the approach generally advocated in the investigation of suggested pheochromocytomas (LECKY et coll 1976) If no abnormality is found at angiography but clinical and laboratory suggestion still remains venous catheterization with selective sampling from the adrenal veins and determination for cathecholamines may be helpful (HARRISON et coll 1967 AGEE et coll 1973 GEORGI et coll 1978)

The association of bilateral medullary adrenal hyperplasia with medullary thyroid carcinoma as in one of the present patients (Case 3) is a rare phenomenon This patient had symptoms compatible with pheochromocytoma and elevated urinary vanillyl mandelic acid CARNEY et coll (1975) reported on an asymptomatic 12 year old girl with medullary carcinoma of the thyroid and high urinary levels of vanillyl mandelic acid suggesting pheochromocytoma Bilateral adrenalectomy was performed and diffuse non nodular adrenal medullary hyperplasia was present It was suggested that diffuse hyperplasia of the adrenal medulla may be the precursor of pheochromocytoma in patients with Sipple s syndrome (multiple endocrine neoplasia type 2)

With the advent of grey scale sonography and computer tomography it has become possible to delineate the normal adrenal gland in a high percentage of cases (SAMPLE 1978 MONTAGNE et coll 1978 BROWNLIE & KREEL 1978) These provide non invasive techniques of high accuracy and will probably in the future become important tools in detecting adrenal pathology in patients with suggested Sipple s syndrome

SUMMARY

Adrenal angiography was performed in 8 patients with Sipple s syndrome Seven patients had pheochromocytomas and one bilateral adrenal medullary hyperplasia In 4 cases the pheochromocytomas were bilateral The angiographic findings are discussed and it is concluded that no typical angiographic appearance of pheochromocytoma appears to exist

ZUSAMMENFASSUNG

Bei 8 Patienten mit Sipple Syndrom wurde eine angiographische Untersuchung der Nebennieren durchgeführt Sieben Patienten hatten Phaochromozytome der Nebennieren Bei einem Patienten lag eine bilaterale medullare Hyperplasie der Nebennieren vor Vier Patienten hatten bilaterale Phaochromozytome Die Befunde werden diskutiert und es wird der Schlussatz gezogen dass es typische angiographische Kriterien bei Phaochromozytomen nicht zu geben scheint

RÉSUMÉ

Une angiographie surrénalienne a été pratiquée chez 8 malades atteints de syndrome de Sipple Sept malades avaient des phéochromocytomes et un une hyperplasie bilatérale de la médullaire surrénalienne Dans 4 cas les phéochromocytomes étaient bilatéraux Les auteurs étudient les signes angiographiques et concluent qu il ne parait pas exister d aspect angiographique typique du phéochromocytome

REFERENCES

AGEE O F KAUDE J and LEPASOON J Preoperative localization of pheochromocytoma Acta radiol Diagnosis 14 (1973) 545

BALTAXE H A LEVIN D C and IMPERATO J L The angiographic demonstration of partially infarcted pheochromocytoma of the adrenal gland Amer J Roentgenol 119 (1973) 793

BROWNLIE K and KREEL L Computer assisted tomography of normal suprarenal glands J Comp Ass Tomogr 2 (1978) 1

CARNEY J A SIZEMORE G W and TYCE G M Bilateral adrenal medullary hyperplasia in multiple endocrine neoplasia type 2 The precursor of bilateral pheochromocytoma Mayo Clin Proc 50 (1975) 3

FRY J K KERR J H THOMAS M L and STARER F The value of aortography in the diagnosis of pheochromocytoma Clin Radiol 18 (1967) 276

GEORGI M CORDES U GUNTHER R PHILIPP T und LENNER V Phlebographische Diagnostik des Phaochromozytoms Fortschr Rontgenstr 128 (1978) 727

HARRISON T S SEATON J F CERNEY J C BOOKSTEIN J J and BARTLETT J D Localization of pheochromocytoma by caval catheterization Arch Surg 95 (1967) 339

HOEVELS J and EKELUND L Angiographic findings in adrenal masses Acta radiol Diagnosis 20 (1979) 337

KEISER H R BEAVEN M A DOPPMAN J WELLS S and BUJA L M Sipple s syndrome Medullary thyroid carcinoma pheochromocytoma and parathyroid disease Ann intern Med 78 (1973) 56

LANNER L [illegible] and ROSENCRANTZ M Arteriographic appearances of pheochromocytoma Acta radiol Diagnosis 10 (1970) 35
LECKY J W WOLFMAN N T and MODIC C W Current concepts of adrenal angiography Radiol Clin N Amer 14 (1976) 309
LJUNGBERG O On medullary carcinoma of the thyroid Acta path microbiol scand Section A (1972) Suppl No 231 p 10
MONTAGNE J P KRESSEL H Y KOROBKIN M and MOSS A A Computed tomography of the normal adrenal glands Amer J Roentgenol 130 (1978) 963
SAMPLE W F Adrenal ultrasound Radiology 127 (1978) 461
SIPPLE J H The association of pheochromocytoma with carcinoma of the thyroid gland Amer J Med 31 (1961) 163
SUTTON S The radiological diagnosis of adrenal tumors Brit J Radiol 48 (1975) 237
ZELCH J V MEANEY T F and BELHOBEK G H Radiologic approach to the patient with suspected pheochromocytoma Radiology 111 (1974) 279

Book review

RADIOLOGY OF THE LIVER By James G McNulty 437 pages 255 illustrations Volume 13 in the series Saunders monographs in clinical radiology Holt Saunders Philadelphia London Toronto 1977 Price £22

The liver has for many years been out of sight for the radiologist However during the last decade new sophisticated techniques such as CT ERCP, PTC grey scale ultrasound and new applications of isotops are available This book is an attempt to compile all such new as well as old techniques and their present possibilities

The book opens with a comprehensive chapter on the normal anatomy of the liver The next chapter 136 pages nearly one third of the book deals with diagnostic methods The investigative techniques illustrated with normal and abnormal findings are described for conventional films for ultrasonic and isotopic techniques computer tomography arteriography portography phlebography examinations of the biliary tract (from oral cholecystography to PTC and ERCP) and contrast examinations of the gastrointestinal tract in liver disease

The following eight chapters describe radiologic abnormalities associated with congenital inflammatory and primary vascular disorders as well as with trauma and neoplasia The final chapter deals with the radiology of the systemic manifestations of liver disease

The aetiology pathology and clinical features of each disorder as well as all the radiologic diagnostic methods are surveyed in an attempt to cover completely all disorders of the liver and their radiologic examination Consequently its treatment of some aspects is cursory The criteria for the diagnosis of some conditions are occasionally scant or absent However some chapters such as those on portal hypertension cirrhosis and tumour of the liver summarize all available information on their subjects and are worthy of careful perusal

The reproductions are of varying quality They are often of too high a contrast lacking the informative grey scale Another imperfection in the reviewer s opinion is their legends Usually they are without anatomic descriptions of the findings and there are often no didactical arrows Even a radiologist with special interest in the liver might have difficulties in their interpretion

The book can be recommended to the young radiologist in training and the general radiologist It ought also prove of interest to the surgeon internist and gastroenterologist with interest in the liver For the radiologist with special interest in liver diseases much of the material will prove to be familiar and too elementary however the book provides a good source of references

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ULTRASOUND, ANGIOGRAPHY AND FINE NEEDLE ASPIRATION BIOPSY IN DIAGNOSIS OF RENAL NEOPLASMS

W KARP and L EKELUND

When a renal mass is demonstrated at urography further examination with ultrasound and angiography are well established diagnostic methods Diagnostic difficulties may however arise in cases of cystic or necrotic carcinoma which may appear as an echo free mass at ultrasound examination or as an avascular or hypovascular mass at angiography In such a situation with equivocal findings the combination of these two modalities with fine needle aspiration biopsy is of great value (EKELUND 1978) It was considered worth while to report the experience in the management of avascular and hypovascular renal neoplasms at this hospital The ultrasound findings were also correlated with the angiographic and histologic results and therefore even a number of hypervascular masses were included in the material

Material and Methods

Ultrasound examination was performed in 182 patients in whom a renal mass was detected at urography Only patients with solid or complex masses at ultra sound and subsequently diagnosed to be tumor were included in the present series which consisted of 23 patients (16 males and 7 females) a^a d from 34 to 84 years Fine needle aspiration biopsy was performed in all cases and angiography in all

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Fig. 1. 64 year old woman with weight loss and high ESR. Non functioning kidney at urography. a) Transverse B scan. Echo free mass with poor transmission of energy suggesting a solid lesion. b) Selective angiography. Narrowed main renal artery with encasement and occlusion of arteries to middle and lower part of kidney. Discrete neovascularity corresponding to renal pelvis (→). Operation: nephrectomy. Histology: pelvic carcinoma.

but one. The findings at these three modalities were then correlated. During the first period the patients were examined with compound B scan and later with a grey scale unit. Both 2.25 and 3.5 MHz focused transducers were employed. The examination technique was similar to that described by SANDERS (1975). The renal masses were divided into two main groups at ultrasound: the first group consisted of tumors producing more echoes than the surrounding kidney tissue and the second group producing less echoes (sometimes predominantly without echoes). The criteria for diagnosing a solid mass were the same as described by GREEN & KING (1976) and include the demonstration of internal echoes in the mass, irregularity of the tumor margins and a poorly defined distal wall.

Parts in the solid tumor without echoes have been considered as necrosis or hemorrhage in so called complex masses. The technique for fine needle biopsy was that usually employed at this department for biopsies guided by angiography as described by TYLÉN et coll. (1976), guided by lymphography as described by GÖTHLIN (1976), by retrograde pyelography as described by EKELUND & GÖTHLIN (1976), and with adaptation to the ultrasonic guided puncture technique described by HOLM et coll. (1972), KRISTENSEN et coll. (1972) and GOLDBERG & POLLACK (1976).

Table 1

Correlation of ultrasound and angiography in 23 cases of renal tumors

Ultrasound		Angiography		
Solid with many echoes	Solid with less or no echoes	Avasc	Hypovasc	Hypervasc
1	2	3		
3	5		8	
6	5			11

Table 2

Correlation of ultrasound and angiography in 6 cases with necrotic tumor

Ultrasound		Angiography		
Solid with many echoes	Solid with less or no echoes	Avasc	Hypovasc	Hypervasc
1	2	3		
	2		2	
	1			1

The special kind of transducer described by GOLDBERG & POLLACK (1973) is used for the ultrasonic guided fine needle biopsies A 15 cm long needle (OD 0 9 *mm* 20–21 gauge) and an aspirating device according to FRANZÉN et coll (1960) were *employed* All angiographies were performed using a catheter introduced per cutaneously via the femoral *artery In all patients* lumbar aortography was per formed as well as selective angiography of both *kidneys* Pharmacoangiography with angiotensin (*Hypertensin N Ciba* Switzerland EKELUND et coll 1972) was employed in some of the cases

The renal masses were classified at angiography as *avascular* hypovascular and hypervascular depending on the absence or presence of tumor vessels and the degree of accumulation of contrast medium during the nephrographic phase The malignant nature of the mass was confirmed by cytology or histology in all cases

Results

Ultrasound A mass in the kidney was demonstrated in all 23 patients Eleven produced more echoes than the surrounding parenchyma thus being solid and 12 produced less internal echoes than the surrounding parenchyma thus being solid or complex but at the same time without evidence of a simple cyst

Biopsy was performed in all patients in 22 guided by ultrasound and in one by angiography In 15 patients the biopsy revealed malignant cells in 14 indicating

a

b

Fig. 2. 43 year old man with hematuria. Calcification in upper pole of kidney. a) Grey scale longitudinal scan. *More echoes in upper pole* (→) than in surrounding parenchyma. Suggestion of tumor. Fine needle biopsy not diagnostic. b) *Selective angiography.* Hypovascular mass in upper pole with localized arterial irregularities suggesting tumor encasement. No definite tumor vessels. *Operation:* nephrectomy. *Histology:* regressive papillary carcinoma.

adenocarcinoma and in one renal pelvic carcinoma. Five of these 15 patients had necrotic tumors.

In one patient the biopsy material consisted of necrotic material only. Angiography revealed a hypovascular carcinoma of the renal pelvis (Fig. 1). Two of the patients, one with the cytologic diagnosis of a simple renal cyst and the other with insufficient cytologic material, later turned out to have necrotic and papillary renal carcinoma respectively. One patient had no malignant cells in the biopsy material. The mass was predominantly without echoes but was not a benign cyst. At angiography a hypovascular mass was demonstrated. Subsequent nephrectomy revealed renal carcinoma. No material sufficient for diagnosis was obtained in the remaining 4 patients. In all of them angiography demonstrated a hypervascular mass and subsequent nephrectomy and histologic examination showed carcinoma. Complications after biopsy were rare. Incidents of transient macroscopic hematuria occurred in 2 cases only.

Angiography. An avascular mass was found in 3 cases, a hypovascular in 8 and a hypervascular in 11.

The results of ultrasound, angiography and pathology were correlated and are summarized in Tables 1 and 2. Of 11 hypervascular tumors, 6 appeared as solid tumors with abundant internal echoes at ultrasound, while 5 lesions contained less

a

b

Fig 3 54-year old man with hematuria and anemia Mass probably solid at nephrotomography a) Grey scale longitudinal scan Deformity of the renal pelvis by a solid mass with a few echoes (→) b) Selective angiography Hypovascular mass lateral in lower pole without sharp demarcation towards renal parenchyma (→) Operation nephrectomy Histology renal carcinoma

echoes than the surrounding normal renal parenchyma Of 8 hypovascular tumors 3 contained abundant internal echoes (Fig 2) and 5 less echoes than the surrounding renal parenchyma (Fig 3) In 3 cases of avascular tumors 2 contained less internal echoes than the surrounding parenchyma (Fig 4) and the other mass more When correlating ultrasound and angiography with the histologic findings it was found that of 6 cases with a necrotic mass 3 were avascular 2 of these predominantly without echoes while the third had a mass producing several internal echoes A fourth and a fifth case both hypovascular had at ultrasound examination a mass producing less internal echoes than the surrounding renal parenchyma The sixth necrotic tumor was hypervascular and predominantly without echoes In the remaining cases without tumor necrosis based on the pathology reports no definite correlation between the angiographic and echographic appearances and the histologic structures could be proved A good correlation was found between the size at ultrasound and at angiography in almost every case

Discussion

It is generally agreed that ultrasound should be the first examination when a mass has been found at urography (Leopold et coll 1973 Smith & Bennett 1975 Sanders Ekelund & Karp 1978) If necessary evaluation of the mass walls by high dose nephrotomography should be performed (Bosniak 1974) The diagnostic

a

b

Fig. 4. 69 year old man with hematuria. Mass in upper pole at urography. a) Grey scale longitudinal scan. Mass with few echoes and *some irregularity of the walls (→), thus with* no indication of a simple cyst. b) Selective angiography. Predominantly avascular mass with slightly irregular arteries in periphery of lesion. No evidence of a simple cyst. Operation: nephrectomy. Histology: necrotic adenocarcinoma.

value of ultrasound is mainly to differentiate between simple renal cysts and neoplasms. However, as MAKLAD et coll. (1977) emphasize, the role of ultrasound is not only to differentiate between these entities but also to delineate the echo-producing mass and make an ultrasonic diagnosis of the renal tumors. Briefly the differential diagnosis between a benign cyst and a tumor is based on the fact that *a cyst is echo free in both high and low gain*, since it contains cyst fluid which is a homogeneous transmitting medium (Fig. 5). The wall should be regular and sharp and very good transmission of sound energy through the cyst must be present. On the contrary, *the solid renal mass* (Fig. 6) is more or less echo producing depending on the tumor contents including blood vessels, tissue, necrosis and hemorrhage, and is often not smooth and has no sharp demarcation. The transmission through the mass is poor as a result of attenuation of energy on internal structures. Between these two categories of renal masses a *third one exists which has both echo free and echo producing areas*, often depending on the presence of hemorrhage and necrosis. It must be categorically emphasized that not all echo-free masses represent simple cysts. GREEN et coll. described 15 masses without echoes which proved to be other entities than simple cysts including abscess, hematoma, renal artery aneurysm, hydronephrosis, and homogeneous or cystic tumor. Several

a

b

Fig 5 Grey scale longitudinal scan of kidney Mass without echoes in lower pole with signs of a simple cyst (→)

Fig 6 Grey scale longitudinal scan of kidney Solid mass (→) with internal echoes renal carcinoma

other reports describe cases with masses without echoes which later turned out to be something else than a simple cyst (GOLDBERG & POLLACK 1971 DOUST et coll 1973 HUNIG & KINSER 1973 HECKMAN et coll 1975 ROCHESTER et coll 1978) The present material includes a few tumors without echoes but all lack the characteristic signs of a simple renal cyst According to GREEN et coll all renal lesions which do not have the criterion of a simple cyst should be subject to further examination In such cases the next step should be either biopsy or angiography depending on the actual situation Diagnostic punctures of renal tumors with cytologic examination was introduced already in 1952 by LINDBLOM Since then fine needle aspiration biopsy has been employed more or less routinely Ultrasound guided biopsy was introduced in 1972 and is now a well-established method It is thus evident that a confirmation of the nature of the renal mass by fine needle aspiration biopsy especially preoperatively may be of great value This method which often leads to a definitive diagnosis is particularly useful in cases with equivocal results at ultrasound and an avascular or a hypovascular mass at angiography The degree of vascularity of renal carcinomas is mainly dependent on the extent of tumor necrosis (EKELUND et coll 1977) and the mass may present as a hypovascular or an avascular lesion LANG (1971) reported 4 cases of cystic tumors all with cytologic evidence of malignancy which had been diagnosed as a cyst at nephrotomography and angiography Furthermore LEOPOLD et coll described two avascular but at ultrasound solid masses which were aspirated and found to be malignant In a recent series of renal cystic lesions 4 patients with avascular tumors at angiography have been described by EKELUND & KARP In 3 of them the diagnosis was obtained by aspiration biopsy Additionally 2 patients had hypovascular renal carcinoma in these cases the diagnostic information was enhanced by pharmacoangiography Histologic examination of all these 6 tumors showed extensive necrosis or hemorrhage

EKELUND described 3 cases of hypovascular tumors predominantly without echoes. Fine needle aspiration biopsy was performed yielding malignant cells. Histologic examination showed a necrotic papillary carcinoma in 2 and a metastatic tumor in the third. The present material includes 6 cases of necrotic carcinoma, 3 of them avascular, 2 hypovascular and one hypervascular. Several authors (POLLACK et coll. 1974, SMITH & BENNETT, ARGER 1976) have emphasized the importance of a diagnostic approach which includes ultrasound, nephrotomography, fine needle biopsy and angiography. A combination of all these methods considerably improves the correct diagnosis and GREEN et coll. state the diagnostic accuracy under such circumstances to be about 100 per cent.

According to GOLDBERG et coll. (1968), LEOPOLD et coll. and STUBER et coll. (197?) the diagnostic accuracy rate of ultrasound alone in the differentiation between simple cyst and tumor is approximately 92 to 96 per cent. However, ultrasound has a few limitations. In approximately 2 per cent a satisfactory result cannot be obtained (STUBER et coll.) depending on obesity, overlying intestinal gas or superimposed skeletal parts. Small intrarenal tumors (less than 2 cm), which give the same echo as the surrounding renal parenchyma, may be difficult to localize and therefore correlation with urography is a sine qua non.

Fine needle aspiration biopsy has been used for many years in the diagnosis of malignancy in various organs. Often the possible risk of dissemination of tumor cells during biopsy has been discussed. ENGZELL et coll. (1971) analysed the possibility of such a spreading in biopsy of lymph node metastases in experiments on rabbits and did not find any evidence of tumor dissemination. These authors came to the same conclusion in a clinical follow-up of 157 patients with pleomorphic adenoma of the major salivary gland and 469 patients with prostatic carcinoma, all diagnosed by fine needle biopsy. VON SCHREEB et coll. (1967) analysed a series of 150 cases of surgically confirmed renal carcinomas. In 77 patients preoperative diagnostic puncture with injection of contrast medium was carried out using needles with an OD of 0.75 to 1.5 mm. In the other 73 patients no puncture was performed. An analysis of the five-year survival rate disclosed no significant difference between the groups and interestingly enough a weak tendency for a better five-year survival rate for the patients with a diagnostic renal puncture. The authors concluded that the risk of spreading cells in diagnostic puncture of renal carcinoma and hence of decreasing the survival rate is negligible. SINNER & ZAJICEK (1976) found only one patient with implantation metastasis at the site of biopsy in a follow-up of 1 264 patients with a malignant pulmonary tumor diagnosed by transthoracic needle biopsy during 1961 to 1974. There seems to be only one report on needle tract seeding of renal carcinoma (BUSH et coll. 1977). These authors described the development of a metastasis in the needle tract 20 months after puncture of a renal adenocarcinoma. After excision the patient has remained free of tumor recurrence for 15 months. It was concluded that the exceedingly rare needle tract seeding should not deter the use of renal cyst aspiration in the radiologic evaluation of renal masses.

Therefore it does not seem contraindicated to take advantage of the increased diagnostic information that may be obtained by fine needle biopsy in equivocal cases The present material also includes one patient with a renal mass and multiple pulmonary metastases in whom histologic diagnosis was obtained by ultrasonic guided fine needle aspiration biopsy The patient was considered inoperable and palliative treatment could be instituted saving the patient from unnecessary angiography as well as explorative surgery

When correlating the ultrasonic findings with the degree of vascularity as seen at angiography 6 of 11 hypervascular tumors were found to be solid (Table 1) When comparing angiographic and ultrasonic findings in 6 necrotic tumors (Table 2) 5 were found to be predominantly without echoes or less echo producing while 3 were avascular and 2 hypovascular Even if the material is not large there seems to be a tendency for angiographically hypervascular tumors to appear solid at ultrasound while avascular necrotic tumors may appear predominantly without echoes This is contrary to the results of MAKLAD et coll who found that the more echo producing tumors had areas of hemorrhage and necrosis whereas less echo producing tumors were homogeneous with no evidence of hemorrhage or necrosis

SUMMARY

The diagnostic approach to a renal mass including ultrasound angiography and fine needle aspiration biopsy is reviewed on the basis of 23 cases The value of the combination of these methods is emphasized especially in tumors which appear without echoes at ultrasound and avascular hypovascular at angiography The findings are correlated and some differential diagnostic problems discussed as well as the possible risk of spreading tumor cells at fine needle aspiration biopsy

ZUSAMMENFASSUNG

Die Erfahrungen bei der Diagnose raumfordernder Prozesse der Nieren mit Ultraschall Angiographie und Feinnadel Aspirationsbiopsie werden anhand von 25 Fallen ausgewertet Der Vorteil des kombinierten Einsatzes dieser Methoden insbesondere bei echographisch uncharakteristischen Befunden und angiographisch avaskularen hypovaskularen Tumoren wird dokumentiert Die Befunde werden zueinander korreliert Differentialdiagnostische Probleme und das Risiko der Tumoraussaat bei der Feinnadel Aspirationsbiopsie werden diskutiert

RESUME

Les auteurs ont revu la conduite du diagnostic d une masse rénale sur la base de 23 cas en utilisant l échotomographie l angiographie et la biopsie aspiration avec une aiguille fine L intérêt de l association de ces méthodes est souligné particulièrement pour les tumeurs qui n ont pas d échos a l échotomographie et qui sont avasculaires ou hypovasculaires a l angiographie Les résultats sont corrélés et les auteurs étudient certains problèmes de diagnostic différentiel ainsi que le danger possible de disséminer des cellules tumorales au cours de l aspiration biopsie avec une aiguille fine

REFERENCES

ARGER P H The value of ultrasound in hypovascular hypernephromas J clin Ultrasound 4 (1976) 371

BOSNIAK M Nephrotomography A relatively unappreciated but extremely valuable diagnostic tool Radiology 113 (1974) 313

BUSH W H BURNETT L L and GIBBONS R P Needle tract seeding of renal cell carcinoma Amer J Roentgenol 129 (1977) 725

DOUST V L DOUST B D and REDMAN H C Evaluation of ultrasonic B mode scanning in the diagnosis of renal masses Amer J Roentgenol 117 (1973) 112

EKELUND L Hypovascular renal tumors An aggressive diagnostic approach required J Urol 119 (1978) 566

— and GÖTHLIN J Fine needle biopsy of metastases at retrograde pyelography directed by fluoroscopy Scand J Urol Nephrol 10 (1976) 261

— and KARP W Evaluation of solitary renal cystic lesions Acta radiol Diagnosis 19 (1978) 321

— GÖTHLIN J and LUNDERQUIST A Diagnostic improvement with angiotensin in renal angiography Radiology 105 (1972) 33

— JONSSON N and LUNDERQUIST A Tumor vessels Angiographic histopathologic correlation Radiologe 17 (1977) 95

ENGZELL U ESPOSTI P L RUBIO C SIGURDSON Å and ZAJICEK J Investigation on tumor spread in connection with aspiration biopsy Acta radiol Ther Phys Biol 10 (1971) 385

FRANZÉN S GIERTZ G and ZAJICEK J Cytological diagnosis of prostatic tumours by transrectal aspiration biopsy A preliminary report Brit J Urol 32 (1960) 193

GOLDBERG B B and POLLACK H M Differentiation of renal masses using A mode ultrasound J Urol 105 (1971) 765

— — Ultrasonic aspiration transducer Radiology 102 (1972) 187

— — Ultrasonic aspiration biopsy transducer Radiology 108 (1973) 667

— — Ultrasonic aspiration biopsy techniques J clin Ultrasound 4 (1976) 141

— OSTRUM B J and ISARD H J Nephrosonography Ultrasound differentiation of ren masses Radiology 90 (1968) 1113

GÖTHLIN J Post lymphographic percutaneous fine needle biopsy of lymph nodes guided by fluoroscopy Radiology 120 (1976) 205

GREEN W M and KING D L Diagnostic ultrasound of the urinary tract J clin Ultrasound 4 (1976) 55

— — and CASARELLA W J A reappraisal of sonolucent renal masses Radiology 121 (1976) 163

HECKMAN H H CLAPP P R and LOWNEY B Pancreatic pseudocyst simulating perinephric abscess Urology 5 (1975) 420

HOLM H H, KRISTENSEN J K RASMUSSEN S N NORTHEVED A and BARLEBO H Ultrasound as a guide in percutaneous puncture technique Ultrasonics 10 (1972) 83

HUNIG R and KINSER J Ultrasonic diagnosis of Wilms tumors Amer J Roentgenol 117 (1973) 119

KRISTENSEN J K HOLM H H RASMUSSEN S N and BARLEBO H Percutaneous puncture of renal masses Scand J Urol Nephrol (1972) Suppl No 15 p 49

LANG E K Coexistence of cyst and tumor in the same kidney Radiology 101 (1971) 7

LEOPOLD G R TALNER L B ASHER W M GOSINK B B and GITTES R F Renal ultrasonography An updated approach to the diagnosis of renal cyst Radiology 109 (1973) 671

LINDBLOM K Diagnostic kidney puncture in cyst and tumors Amer J Roentgenol 68 (1952) 209

MAKLAD N F CHUANG V P DOUST B D CHO K J and CUVRAN J E Ultrasonic characterization of solid renal lesions Echographic angiographic and pathologic correlation Radiology 123 (1977) 733

POLLACK H M GOLDBERG B B and BOGASH M Changing concepts in the diagnosis and management of renal cysts J Urol 111 (1974) 326

ROCHESTER D ARONSON A J BOWIE J D and KUNZMANN A Ultrasonic appearance of acute poststreptococcal glomerulonephritis J clin Ultrasound 6 (1978) 49

SANDERS R C Renal ultrasound Radiol Clin N Amer 13 (1975) 417

VON SCHREEB T ARNER O SKOVSTED G and WIKSTAD N Renal adenocarcinoma Is there a risk of spreading tumor cells in diagnostic puncture? Scand J Urol Nephrol 1 (1967) 270

SINNER W N and ZAJICEK J Implantation metastasis after percutaneous transthoracic needle aspiration biopsy Acta radiol Diagnosis 17 (1976) 473

SMITH E H and BENNETT A H The usefulness of ultrasound in the evaluation of renal masses in adults J Urol 113 (1975) 525

STUBER J L TEMPLETON A W and BISHOP K Ultrasonic evaluation of the kidneys Radiology 104 (1972) 139

TYLÉN U ARNESJÖ B LINDBERG L G LUNDERQUIST A and ÅKERMAN M Percutaneous biopsy of carcinoma of the pancreas guided by angiography Surg Gynec Obstet 142 (1976) 737

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PERCUTANEOUS TRANSPERITONEAL FLUOROSCOPY-GUIDED FINE-NEEDLE BIOPSY OF LYMPH NODES

JAN GÖTHLIN

Paraaortic lymph node biopsies with a paravascular approach were first used by RÜTTIMAN (1968), the transvascular approach was tried by LÜNING & ROMANILA (1969) and LÜNING et coll. (1972), and KEINERT et coll. (1971) and KEINERT (1973) used both the translumbar and the transvascular approach. The transperitoneal approach was reported by GÖTHLIN (1976) and also by LAGERGREN & FRIBERG in the same year. The same approach was used by WALLACE et coll. (1977) and ZORNOSA et coll. (1977).

The percutaneous transperitoneal approach with the aid of fluoroscopy may now be regarded as established and the experiences in 107 patients are now reported.

Material and Methods

The series consisted of 63 men (examined 64 times) and 44 women, 45 of these having been presented previously (GÖTHLIN). Most patients were given 5 to 10 mg of valium and 0.5 mg of atropine before the examination. With the patient in supine position 5 ml of mepivakain 1 % was infiltrated in the skin, fat and muscles of the ventral abdominal wall immediately vertical to the lymph node or nodes to be examined. Care was taken not to inject anesthetic into the lymph nodes. In 95 patients an entrance needle, ID/OD 1.2/1.6, length 40 mm, was used, through which a thinner needle was introduced until its tip entered the intended lymph node. The procedure was controlled with single or biplane fluoroscopy. The thinner needles used were

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Table 1

Primary disease in 63 males and 44 females

Diagnosis	No of cases
Seminoma and malignant testicular teratoma	11
Carcinoma of kidney urinary bladder ureter and penis	35
Carcinoma of vulva cervix and uterus	19
Sarcoma	4
Hodgkin s disease	31
Lymphosarcoma	4
Leukemia	2
Fibrosis after hydantoin treatment	1

Luer Loc OD 0 9 mm length 150 mm (Mediplast Sweden) Franzen needle OD 0 6 mm length 200 mm (FRANZEN et coll 1960) or Skinny needle OD 0 7 mm length 200 mm (Cook Inc USA) When the tip of the needle was within the intended area of the lymph node confirmed by fluoroscopy and the node moving with the tip of the needle aspiration was done using a 10 ml syringe in a handle (FRANZÉN et coll) while the needle was moved up and down 1 to 2 mm and slowly rotated Smears were made on glass and sent for immediate cytologic examination In most cases the patients remained on the radiographic couch with the entrance needle in place until the preliminary result of the cytologic examination was obtained If that was not satisfactory repuncture could be performed within 10 to 15 min

Results

The primary disease appears in the Table As only pedal lymphangiography had been employed the urogenital carcinomas dominated (65 patients) with Hodgkin s disease as second (31 patients)

The lymphographic results were uncertain in 69 cases with malignant disease In 46 of these metastatic involvement was demonstrated at node biopsy confirmed at operation in 43 cases while 3 were primarily irradiated In 2 patients the material obtained was not representative while in a further 2 patients the needles were not long enough to reach the intended area because of obesity In 19 cases the lymph nodes were normal or showed postlymphographic reactions all confirmed at operation

General lymphatic disease affecting lymph nodes was suggested in 38 patients 31 with malignant lymphoma 4 with lymphosarcoma 2 with leukemia and 1 with fibrosis after hydantoine treatment Involvement was found in 12 6 of which were demonstrated also at operation (6 patients were primarily irradiated) In 16 patients the biopsied lymph nodes were normal or demonstrated postlymphographic reac

FROM THE DEPARTMENT OF RADIOLOGY HAUKELAND SYKEHUS UNIVERSITY OF BERGEN MEDICAL SCHOOL N 5016 BERGEN NORWAY

PERCUTANEOUS TRANSPERITONEAL FLUOROSCOPY-GUIDED FINE-NEEDLE BIOPSY OF LYMPH NODES

JAN GÖTHLIN

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Representative material for cytology is obtained in 70 per cent at puncture of palpable lymph nodes in Hodgkin s disease (ZAJICEK 1974) LAGERGREN & FRIBERG reported less favourable results when performing biopsies during fluoroscopy but the results in the present series contradict those findings It appears that the method could be used in staging Hodgkin s disease

In conclusion it may be said that the percutaneous transperitoneal fluoroscopy guided fine needle biopsy is a safe highly reliable method of determining metastatic involvement of lymph nodes and fairly accurate in general lymphatic disease

SUMMARY

After lymphography from the foot with uncertain findings fine needle biopsy during fluoroscopy was performed in 107 patients In 69 patients with possible metastases involvement was demonstrated in 46 confirmed in 43 at operation Lymph node involvement by general lymphatic disease was suggested in 38 patients with biopsy confirmation in 12 In metastatic disease non representative material was obtained in only 2 patients in general lymphatic disease in 10 No significant complications occurred and the side effects were small

ZUSAMMENFASSUNG

Nach Lymphographie vom Fuss mit unklaren Befunden wurde Feinnadelbiopsie unter Durchleuchtung bei 107 Patienten vorgenommen Bei 69 Patienten mit möglichen Metastasen wurde eine Beteiligung bei 46 nachgewiesen die bei 43 bei der Operation bestätigt wurde Eine Beteiligung der Lymphknoten durch eine allgemeine lymphatische Erkrankung wurde bei 38 Patienten vermutet bei 12 wurden diese durch Biopsie bestätigt Bei metastatischer Erkrankung wurde nur bei 2 Patienten ein nicht repräsentatives Material erhalten bei generell lymphatischer Erkrankung bei 10 Keine wesentlichen Komplikationen traten auf und die Nebeneffekte waren gering

RÉSUMÉ

Après lymphographie par voie pédieuse ayant donné des résultats incertains une biopsie avec une aiguille fine sous radioscopie télévisée a é é effectuée chez 107 malades Chez 69 malades pouvant avoir des métastases une atteinte lymphatique a été mise en évidence dans 48 cas confirmés par opération dans 43 cas Une atteinte des ganglions lymphatiques par une maladie lymphatique généralisée a eté soupçonnée chez 38 malades et confirmée par biopsie chez 12 malades Le prélèvement biopsique à l aiguille n a ète non significatif que chez 2 malades dans les cas d affection métastatique et chez 10 malades en cas d affection lymphatique généralisée Il n y a pas eu de complication importante et les effets secondaires sont petits

REFERENCES

FORSGREN L and ORELL S Aspiration cytology in carcinoma of the pancreas Surgery 73 (1973) 38

FRANZÉN S GIERTZ G and ZAJICEK H Cytological diagnosis of prostatic tumours by transrectal aspiration biopsy A preliminary report Brit J Urol 32 (1960) 193

tions Non representative material was obtained in 10 patients most of them early in the series

No pain occurred in 41 patients and slight pain in 46, while 3 reported moderate pain Tenderness in the abdominal wall at the puncture site the day after the procedure occurred in 16 patients while one had pain in the abdomen leading to radiography Nothing abnormal was revealed and the following day the patient was symptom free No contraindications have been set

Discussion

In metastatic disease sufficient material was obtained with the 0 9 mm needle at least after repuncture Only in 2 patients was the material not representative Aspiration alone is not enough moving the tip up and down is of value Some type of hook or screw inside the needle could be used (RÜTTIMAN LÜNING et coll) but the present results indicate that it is not necessary, at least in metastatic nodes On the other hand in general lymphatic disease, where the 0 6 or 0 7 mm needle yielded the best results representative material could not be obtained in some cases (mainly nodular sclerosis) In these cases another type of aspirating instrument could be useful LAGERGREN & FRIBERG found a 0 9 to 1 2 mm needle to be best suited for biopsy of lymphomas When applying the local anesthetic it is important not to inject into the lymph nodes, as the cells then become distorted The entrance needle was most useful when several punctures in the same area were performed and at repuncture after a negative cytologic diagnosis The patient could remain on the radiographic couch waiting for a preliminary cytologic report

Biplane fluoroscopy was most helpful in puncture of paraaortic lymph nodes but was of less value in the pelvic region However, it is quite possible to puncture para aortic nodes also using single plane fluoroscopy especially if a cradle is used The size of the lymph nodes does not affect the degree of success in puncturing (GÖTHLIN)

LAGERGREN & FRIBERG used the dorsal approach in several of their 158 cases Some difficulties were encountered when guiding the fine needle through the lumbar musculature The ventral approach is obviously easier with the exception of very obese patients In the present material nodes in the abdomen as high as Th 12 as well as some mediastinal nodes have been successfully punctured with the ventral approach In the present series the tip of the biopsy needle was directed into the filling defect of a lymph node or into the marginal zone around it in metastatic disease In general lymphatic disease at least two biopsies from different parts of the supposedly involved node have been performed

No significant complications have occurred despite the fact that bowel pancreas blood vessels or kidney tissue may be traversed by the needle As it has a small diameter it does not constitute any danger (FORSGREN & ORELL 1973 HANCKE et coll 1975 HOLM et coll 1975 TYLÉN et coll 1976) As side effects have been reported pain when hitting a nerve and pain for a couple of days in the lumbar musculature (LAGERGREN & FRIBERG)

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IMAGE ENHANCEMENT BY DIGITAL ANALOG FILTRATION

II Tests of filters

A Hemmingsson B Jung H Lundqvist and A Strömlid

In diagnostic radiology the primary aim has often been to produce films of high contrast and sharpness. These properties can, however, render the evaluation difficult or even impossible. Thus the image contains non essential details which may interfere with the perceptibility of a lesion, and enhancement of the contrast and sharpness of the image may increase the distracting effect of these details. This is illustrated by the fact that more than 2 cm of a vertebral body may have to be destroyed by a metastasis before it is perceptible. Without superimposition of bone trabeculae in the intact part of the vertebral body considerably smaller destructions would be clearly visible (Bokström 1953). Other disturbances may be caused by lung structures, grid lines (Reichmann & Strid 1976) and quantum noise (Rossmann 1963). Similar problems are encountered in computer tomography where the quantum noise is marked in films taken with an acceptable skin dose (Hounsfield 1976). Common to all these disturbing structures is that in relation to the lesion, e.g. bone or lung metastases, or lesions of soft tissue structures in the roentgenogram or the computer tomogram they have a high spatial frequency.

Enhancement of scintigrams by *frequency filtration* has been a routine procedure for the last few years. In roentgenograms *frequency filtration* has been used mainly to increase the perceptibility of the high frequency structures in the image by, for example, subtraction (Ziedses des Plantes 1961), soft focus subtraction or automatic

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GÖTHLIN J H Post lymphographic percutaneous fine needle biopsy of lymph nodes guided by fluoroscopy Radiology 120 (1976) 205
HANCKE S HOLM H H and KOCH F Ultrasonically guided percutaneous fine needle biopsy of the pancreas Surg Gynec Obstet 140 (1975) 361
HOLM H H PEDERSEN J F KRISTENSEN J K RASMUSSEN N S, HANCKE S and JENSEN F Ultrasonically guided percutaneous puncture Radiol Clin N Amer 13 (1975) 493
KEINERT K Erfahrungen mit der zytologischen Punktion lymphographisch angefärbter Lymphknoten in verschiedenen Regionen Radiol diagn (Berl) 13 (1972) 680
— *SCHINDLER S und SCHAUMANN E Lymphknotenbiopsie zur zytodiagnostischen Sicherung* lymphographischer Befunde Radiol diagn (Berl) 12 (1971) 244
LAGERGREN C och FRIBERG S Aspiration biopsy of lymph nodes after lymphography (In Swedish) Proceedings of the Swedish Society of Medical Radiology 5 (1976) 14
LÜNING M. Ein Biopsiebesteck zu paravasaler Punktion kontrastierter iliakaler Lymphknoten Fortschr Röntgenstr 113 (1970) 78
— und ROMANIUK P A Technik der paravasalen Punktion kontrastierter iliakaler Lymphknoten nach Rüttiman Radiol diagn (Berl) 10 (1969) 361
— GSTREIN P und VOGLER H Überprüfung lymphographischer Befunde durch die paravasale Punktion kontrastierter Lymphknoten des Beckens Dtsch Gesundh Wes 27 (1972) 316
RÜTTIMAN A Iliac lymph node aspiration biopsy through paravascular approach Preliminary report Radiology 90 (1968) 150
TYLÉN U ARNESJÖ B LINDBERG L G LUNDERQUIST A and ÅKERMAN M Percutaneous biopsy of carcinoma of the pancreas guided by angiography Surg Gynec Obstet 142 (1976) 142
WALLACE S *JING B S and ZORNOSA J Lymphangiography* in the determination of the extent of metastatic carcinoma The potential value of percutaneous lymph node biopsy Cancer 39 (1977) 706
ZAJICEK J Aspiration biopsy cytology Part I Cytology of supradiaphragmatic organs *In* Monographs in clinical cytology p 90 Edited by G L Wied S Karger Basel 1974
ZORNOSA J JONSSON K WALLACE S and LUKEMAN J M Fine needle aspiration biopsy of retroperitoneal lymph nodes and abdominal masses An updated report *Radiology* 125 (1977) 87
— WALLACE S GOLDSTEIN H M LUKEMAN J M and JING B S Transperitoneal percutaneous retroperitoneal lymph node aspiration biopsy Radiology 122 (1977) 111

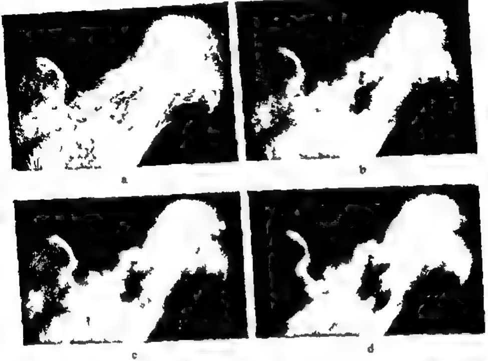
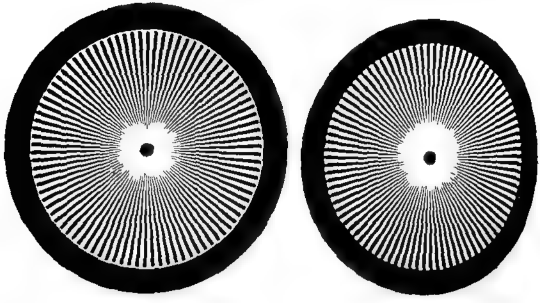


Fig 2 a) Original film of femoral specimen b) Low pass filtration with a 4 mm × 4 mm matrix side c) with a 6 mm × 6 mm matrix side d) with a 10 mm × 10 mm matrix side and e) asymmetric band pass filtration with a 4 mm × 4 mm matrix side of original film

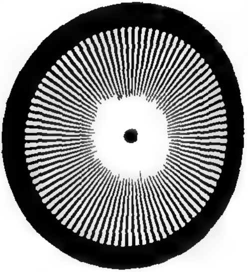
of this device with the use of different *digital filters* is now reported and later the results of the clinical application of the method will appear

Material and Methods

The equipment described in Part I was used Original films were exposed of (1) a lead stellate test object (Fig 1) (2) a femoral specimen with a bore hole through the neck and a sclerotic lesion at the border between the middle and lateral parts of the



a b



c

Fig 1 a) Original film of stellate test object b) Low pass filtration with a 2 mm × 2 mm matrix side and c) low pass and band pass filtration with a 5 mm × 5 mm matrix side of original film

dodging printing (SCHOTT 1967 KUNDEL et coll 1969 LACONI et coll 1972 KILGORE & GREGG 1974) In recent years reports on reducing disturbance by high frequency structures have also appeared (KUNDEL et coll 1972 ZISKIN & SHEA 1972) but the results have not been promising However reports by GOODENOUGH et coll (1974) in particular indicate that it should be possible to improve the diagnostic possibilities in angiography by diminishing the disturbing content of the image Therefore it seemed of value to analyse the possible diagnostic improvement by frequency filtration

A device for filtering conventional roentgenograms with a digital technique has been constructed and described in Part I (CEDERLUND et coll 1979) The function

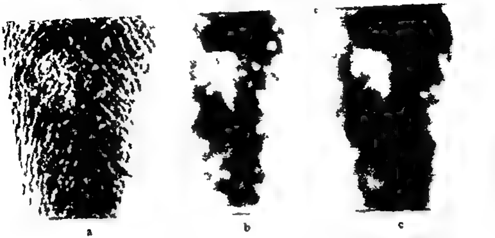


Fig 3 a) Original film of bone specimen with its superimposed 1 cm soft tissue-equivalent pellet b) Low pass filtration with a 4 mm 4 mm matrix side and c) with a 5 mm 5 mm matrix side of original film

was clearly visible (Fig 3 a b) A tendency to an appearance of false small rounded structures was also noted On filtration with a smoother low pass filter (Fig 4 a) almost corresponding to pure smoothing the interference from bone structures was further diminished but at the same time the sharpness of the pellet contour was considerably reduced (Fig 3 c) This contour was thus more perceptible when the more typical low pass filter was used (Fig 3 b)

Discussion

The modulation transfer function of the device is satisfactory if it is used for band pass and low pass filtration with elimination of frequences above about 2 mm^{-1} (CEDERLUND et coll) The results of band pass and low pass filtration with filters of different properties showed that the procedure altered the image in the expected way (Figs 1 2 3) This device is therefore suitable for testing the possibilities of different filters to improve the diagnostic ability and in view of the large variability of different types of filters it should be superior to the TV technique described by KUNDEL et coll (1969) and FUCHS et coll (1972) among others

The perceptibility of the bore hole and of the sclerotic bone lesion as well as of the rounded 1 cm soft tissue structure with superimposed spongy bone was improved with low pass filtration with elimination of frequencies above about 0 5 mm^{-1} This observation is in accordance with hypotheses presented previously (e g HEMMINGSSON et coll 1972 1975 HEMMINGSSON & LOFROTH 1976) The greater perceptibility of these structures with low pass filtration than with smoothing is due to the fact that the sharpness of the contours of the low frequency structures is better retained than when filtering is performed by producing blurring (HEMMINGSSON

neck caudal to the bore hole (Fig 2) and (3) a bone specimen with a superimposed soft tissue equivalent pellet 1 cm in diameter simulating a bone metastasis (Fig 3) The filtered film was recorded on the green light sensitive film Trimax XM (3M)

Image enhancement of the original films was performed by digital frequency filtration with band pass and low pass filters and filters with an edge enhancing effect The characteristics of the different filters are given in Fig 4 The calculations were performed by a desk calculator (HP 9821) under simplified assumptions Thus it was assumed that the projected image of the diode matrix on the object consisted of 10 × 10 square elements with constant light over the surface The square elements were also assumed to lie edge to edge The effect of these simplified assumptions probably influenced the modulation transfer function most strongly at the highest frequencies

Results

Smooth low pass filtration (Fig 4 a) of the image of the stellate test object altered the image in the expected way With a 2 mm × 2 mm matrix one line pair per mm was visible (Fig 1 b) The filter effect was relatively similar in the two dimensions On filtration of the test object image with a filter with both low pass and band pass properties (Fig 4 b) and with a 5 mm × 5 mm matrix resolution of just under a half line pair per mm was achieved (about 4 line pairs per 10 mm) which is also in accordance with the modulation transfer function of the filter (Fig 1 c) In agreement with the calculated properties of the filter around 4 to 5 inverse matrix sides the grid lines again became visible at just under one line pair per mm (7–8 lines per 10 mm) This effect was most clear in one dimension, suggesting that the properties of this filter are not completely symmetric

On filtration of the image of the femoral specimen with the same filter (Fig 4 b) with a 4 mm × 4 mm matrix the structures with the highest frequency in the image the bone trabeculae were almost eliminated (Fig 2 b) and this effect was further accentuated when the size of the matrix was increased to 6 mm × 6 mm (Fig 2 c) The perceptibility of the bore hole in the neck of the femur and of the sclerotic bone lesion in the lateral part of the femoral neck below the bore hole was better in the filtered images When a low pass filter (Fig 4 c) and a 10 mm × 10 mm matrix were used, the image of the spongy bone structure was almost completely abolished while the bore hole in the neck of the femur as well as the sclerotic lesion was clearly visible The outlining of the bore hole and the sclerotic lesion was relatively well retained in the filtered image (Fig 2 d) When the image of the femoral specimen was filtered with an asymmetric band pass filter (Fig 4 d) with a 4 mm × 4 mm matrix the vertical contours were enhanced while the horizontal ones were almost completely eliminated (Fig 2 e)

When the image of the bone specimen with its superimposed soft tissue equivalent pellet was filtered with a low pass filter (Fig 4 e) with a 4 mm × 4 mm matrix the images of the bone trabeculae were similarly abolished while the pellet

lesion still had relatively good sharpness with this strong filtration of the image Filters with marked low pass properties would seem preferable to smooth low pass filters

The asymmetric band pass filter almost completely eliminated the structures in one direction One future use of such filters might be to eliminate disturbing grid lines in the image However normal possibly diagnostically important structures with the same orientation are eliminated at the same time As the grid lines have a relatively high spatial frequency (GOODENOUGH et coll 1974) they are substantially reduced even with the low pass filters described and these filters are therefore probably to be preferred The same should apply to CT scans where the noise can be reduced by low pass filtration improving the perceptibility of soft tissue structures (BERGSTRÖM & SUNDMAN 1976)

SUMMARY

The function of a device for frequency filtration of roentgenograms with digital filters has been tested with the use of different filters The image was altered in the expected way which means that the device is suitable for investigating the possibilities of different filters to improve the diagnostic ability The results of the tests indicate that improvement should be achieved by low pass filtration

ZUSAMMENFASSUNG

Die Funktion einer Anordnung zu Frequenz Filtrierung von Rontgenbildern mit digitalen Filtern wurde unter Verwendung von verschiedenen Filtern untersucht Das Bild wurde in der erwarteten Weise verandert Dieses bedeutet dass die Anordnung eine Beurteilung erlaubt welche Moglichkeiten die verschiedenen Filter haben die diagnostische Anwendbarkeit zu verbessern Die Ergebnisse der Versuche deuten darauf hin dass die Verbesserung durch Kurz pass Filter erreicht werden kann

RÉSUMÉ

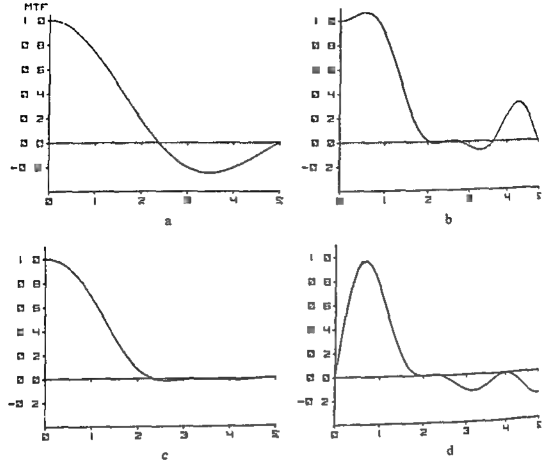
La fonction d un appareil de filtration de frequence des radiographies au moyen de filtres digitaux a été testee avec différents filtres L image a été modifiee de la façon attendue ce qui signifie que l appareil convient pour étudier les possibilites de différents filtres pour ameliorer l efficacite diagnostique Les resultats de ces essais montrent qu une amélioration devrait être obtenue par une filtration passe bas

REFERENCES

BERGSTRÖM M and SUNDMAN R Picture processing in computed tomography Amer J Roentgenol 127 (1976) 17

BOKSTRÖM J Principles of vertebral tomography Acta radiol (1953) Suppl No 103

CEDERLUND J HEMMINGSSON A JUNG B LUNDQVIST H and MOBERG H-O Image enhancement by digital analog filtration I Technical description of device Acta radiol Diagnosis 20 (1979) 154



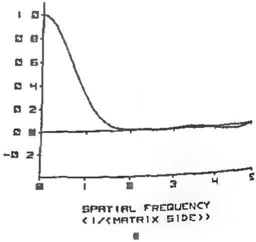


Fig 4 Modulation transfer functions of the filters used in a) Figs 1 b and 3 c b) in Figs 1 c and 2 b c c) in Fig 2 d d) in Fig 2 e and e) in Fig 3 b

et coll 1972) With low pass filtration frequencies above about 0 5 mm^{-1} are eliminated and as a result the disturbing structures largely disappear from the image The sharpness of the lesion in question is thus retained The best perceptibility of relatively large bone lesions with a cross section of 1 cm or more was obtained by low pass filtration with elimination of frequencies above about 0 2 mm^{-1} Thus the

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RELEVANCE OF RADIOGRAPHIC RESOLUTION CAPACITY

S REICHMANN K ÅSTRAND and K G STRID

Resolution capacity is one of the most commonly used conventional parameters designed for describing image quality By definition it implies a figure indicating how many black and white line pairs per mm can be distinguished In clinical radiography this factor has been widely employed as a measure of image unsharpness In conventional photography (PERRIN 1966) however the concept of sharpness is treated as a more complex function determined by resolution capacity and acutance The latter term is more directly related to the subjective impression of sharpness than is resolution capacity Both factors affect the impression of distinctness obtained from the image Still they are not closely interrelated An image with high acutance giving an impression of high sharpness may display low resolution capacity and vice versa However the implications of acutance in clinical radiography are largely unknown Instead whether justified or not investigations concerning radiographic sharpness have so far been focused upon resolution capacity The main line of earlier thinking in this area has been the extension of resolution capacity into the mathematically more sophisticated modulation transfer function (MTF) (MORGAN et coll 1964 PFEILER & KUHN 1973 ARNOLD et coll 1976)

Resolution capacity is often evaluated in a simplified manner As radiographic object a grid consisting of lead bars with increasing line pair density is used Resolution capacity is then identified as the highest line pair density resolvable by the radiographic system This technique is quite attractive since it may be carried out in a

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FUCHS W A MESSERSCHMID U HERREN U and STECK W Electronic detail enhancement in roentgen television Invest Radiol 7 (1972) 140
GOODENOUGH D J DOI K and ROSSMANN K Optical spatial filtering of radiographic images with binary filters Radiology 111 (1974) 433
HEMMINGSSON A and LÖFROTH P O Xeroradiography and conventional radiography in examination of the larynx Acta radiol Diagnosis 17 (1976) 723
— JUNG B and LUNDQVIST H Soft tissue intensification in frontal roentgenography of the larynx Acta radiol Diagnosis 12 (1972) 593
— — and LÖNNERHOLM T Perception of simulated lesions in the lung Acta radiol Diagnosis 16 (1975) 494
HOUNSFIELD G N Picture quality of computed tomography Amer J Roentgenol 127 (1976) 3
KILGORE R A and GREGG E C Transfer functions for xeroradiographs and electronic image enhancement systems Optic Engin 13 (1974) 130
KUNDEL H L REVESZ G and STAUFFER H M Evaluation of a television image processing system Invest Radiol 3 (1968) 44
— — — The electro optical processing of radiographic images Radiol Clin N Amer 7 (1969) 447
— — ZISKIN M L and SHEA F J The image and its influence on quantitative radiological data Invest Radiol 7 (1972) 187
LACONI A SASSO F S e POLIZZI A Riproduzione e magnificazione dei radiogrammi con LogEtron (In Italian) Minerva med 63 (1972) 4245
REICHMANN S and STRID K G Adverse effects of stationary grids Acta radiol Diagnosis 17 (1976) 741
ROSSMANN K Spatial fluctuations of X ray quanta and the recording of radiographic mottle Amer J Roentgenol 40 (1963) 863
SCHOTT O Elektronische Informationsaufbereitung in der Rontgendiagnostik Elektromedizin 12 (1967) 1
ZIEDSES DES PLANTES B G Subtraktion Georg Thieme Stuttgart 1961
ZISKIN M C and SHEA F J Linear spatial frequency filtering for enhancement of radiographic images Radiology 103 (1972) 101

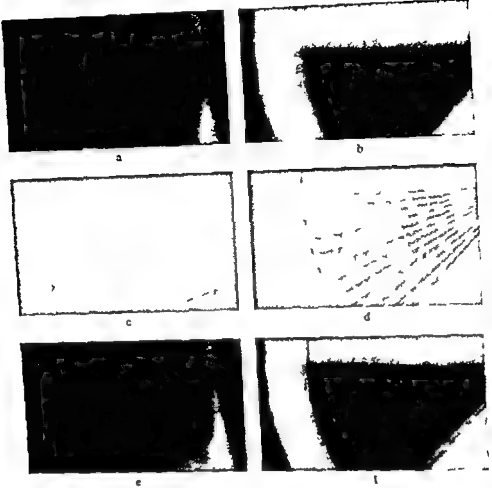

Fig 1 Tomographic depiction of a slice of a vertebral body (a, c e) and a star shaped lead resolution phantom (b d f) The objects were situated at the same level outside the tomographic plane giving rise to blurred images (a b) Pseudo-resolution in (b) On top of this blurred image a second exposure (c d) was made using a low radiation dose the tomograph being motionless The resulting images (e f) display a great difference in image quality for the star-shaped phantom (f) the image of the vertebral body (e) being basically unchanged The difference is caused by the greater attenuation difference of the star shaped phantom as shown by a film exposed only to the low dose exposure when the tomograph was motionless (c d) For the star shaped phantom resolution is mainly a matter of sharpness but for the biologic object it also depends on the signal noise ratio

of vertebral body In this way a film had been produced where the resolution phantom suggested good sharpness properties but where the biologic object was actually very poorly depicted The explanation is obvious when the simple sharp exposures (Fig 1 c d) are scrutinised The attenuation differences within the resolution phantom were large enough to yield an informative image even for the limited exposure used in that case On the other hand the attenuation differences inherent in the trabeculae

standardized way, without taking into account such factors as tube potential or presence and screening of secondary radiation in the practical clinical situation Thus, the test yields a numerical value which is often claimed to be relevant for all types of object tube potential etc In previous reports (SELIN et coll 1975 SELIN & REICHMANN 1977, REICHMANN et coll 1978, REICHMANN & ÅSTRAND 1979) several sources of error inherent in this simplified evaluation procedure have been pointed out Since the misuse of resolution phantoms of the type described is very widespread this matter is now treated more comprehensively than before

Experiments

Two simple experiments were performed In the first one a star shaped resolution phantom made of 0 05 mm lead was depicted together with a thin slice of spongious bone from a vertebral body In order to obtain different levels of resolution capacity these two objects were depicted in a tomograph (Polytome nominal focus size 0 6 mm × 0 6 mm) The slice and the resolution phantom were situated at the same level The tomographic plane lay outside this level at a defined distance Unsharpness was created by means of tomography utilising an optimised movement according to ÅSTRAND & REICHMANN (1974) This movement created a blurring practically free from technical sources of error In this way the two objects were depicted onto an industrial non screen film (Kodak Industrex C) which was placed in a cassette without intensifying screens in order to ensure well defined geometric conditions The film was developed according to DEICHGRÄBER et coll (1974) The exposure was made at a tube potential of 60 kV and a mAs value sufficient to yield a proper exposure (Fig 1 a b) The quantity of blurring was varied so that the penumbra of unsharpness in one case was 1 mm and in another 2 5 mm A second image was then obtained at an exposure amounting to 1/10 and 1/5 respectively, of the mAs value used for the two blurred alternatives In this case no tomographic motion was used, the radiographic focus being at zenith In this way images of low photographic density and low unsharpness were obtained (Fig 1 c d) Although of low density the films were not underexposed in the general sense of the term since one absorbed roentgen photon always creates at least one developable silver halide grain in a non screen exposure (BACKSTRÖM & LUNDH 1959) Despite low photographic density the films thus displayed all the information detectable in the radiation relief absorbed by the recording medium A third film was then obtained where the two exposures were combined in one and the same film Thus on top of the blurred image with 1 mm penumbra a sharp exposure of 1/10 additional dose was added, and on top of the image with 2 5 mm penumbra a sharp exposure of 1/5 additional dose was made (Fig 1 e f) Due to the great exposure latitude of the film used this small additional exposure did not result in overexposure The addition of a small but sharp exposure to the greatly blurred image gave rise to a clear change in the depiction of the resolution phantom no great difference being detectable in the films depicting the slice

Fig 3 The resolution phantom illustrated in Fig 2 depicted with the same pair of intensifying screens (Kodak X omatic Regular) using films of different sensitivity the exposure in (b) being 12 times higher than in (a) Three line pair densities are included (→) In (a) only the lowest spatial frequency may be considered as resolved resolution being limited by quantum mottle Lowering of this mottle (b) gives rise to increased resolution for the type of signal used in this case

The usefulness of the phantom is illustrated by the following experiment The phantom was exposed in air at 60 kV tube potential additional filtration 1 mm iron Three intensifying screen pairs were used viz Kodak X omatic Regular Kyokko LH 2 and Siemens Diamant Super the screens being of nearly the same speed Apart from the plexiglass phantom the star shaped lead phantom was also included in the view field When a conventional roentgen film was used (Agfa Gevaert Curix RP 1) the three screens gave a resolution of one line pair per mm of the plexiglass phantom The resolution for the lead phantom was considerably higher This difference indicated that the resolution capacity for the plexiglass phantom was noise limited rather than MTF limited For this reason a low speed film was used (Kodak Industrex C) leading to a 12 fold increase in exposure At the same time the resolution capacity for the plexiglass phantom increased so that 1 4 line pairs per mm could be distinctly resolved and 2 line pairs per mm were suggested (Fig 3) Thus resolution capacity was improved despite the fact that unsharpness remained unchanged This dose dependency of resolution capacity could not be demonstrated with the high-contrast lead resolution phantom

Discussion

Achievement of optimum performance in radiographic imaging systems is still attempted with surprisingly little attention being paid to the object to be imaged Phantoms designed to behave like the human body are large and clumsy and difficult to construct Therefore it is tempting to use small phantoms instead preferably made of a sheet of metal Data obtained from radiography of such metal objects

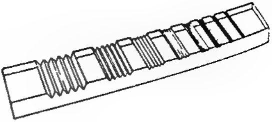

Fig 2 Drawing of a resolution phantom where contrast decreases with increased number of line pairs per mm The phantom was cut in a block of plexiglass

of the spongious bone were not sufficient to yield any informative signals in this type of exposure For this reason a really sharp exposure on top of the blurred one was obtained only for the lead phantom causing a difference in final image appearance, while no further information was obtained from the biologic specimen with its smaller attenuation differences This implies that the signal/noise ratio in the sharp exposure was good enough for changing the appearance of the lead phantom image whereas it was insufficient in the case of the vertebral body This in turn suggests that resolution is not only a matter of how the information is spread in a sideways direction by means of focus unsharpness diffusion of light in intensifying screens etc it is also a matter of the signal/noise ratio This means that the magnitude of the attenuation differences and the noise level of the radiographic system cannot be left without regard when resolution capacity is discussed to the extent that has generally been the case

The shortcomings of the classical resolution phantom made of lead are mainly caused by the fixed attenuation difference This effect is especially obvious at high spatial frequencies (a high number of line pairs per mm) If for example a common biologic object such as a blood vessel is considered it is immediately realised that a large vessel gives rise to a broad image in the film but it also yields a high attenuation difference due to the large dimension of the vessel in the direction of the roentgen rays The fine vessel gives rise to a fine detail in the image simultaneously characterised by a small attenuation difference as compared with that of the large vessel even if the concentration of contrast medium in the vessels is identical This means that if a line pair resolution phantom is to be constructed it should in principle give rise to a decreasing attenuation difference when the number of line pairs per mm is increased Furthermore the attenuation difference should be continuously variable Such a resolution phantom was constructed being tested in the second experiment

A drawing of the phantom appears in Fig 2 The phantom was cut in a plexiglass block the cut section shape of the lines being triangular The line pair density as well as the depth of the lines were changed by a factor $\sqrt{2}$ between consecutive steps entailing a decreasing attenuation difference with a rising number of line pairs per mm When exposed as it is the phantom yields an image resulting from the attenuation difference of plexiglass in relation to air The phantom may be immersed in fluid containing various high absorbing substances such as iodinated contrast media the concentration of which may be varied

obviously gave rise to a noise limitation of resolution when a conventional roentgen film was used The clearest proof of this is that resolution increased when the same screens were combined with a film of lower sensitivity The particular property of an intensifying screen that gives good resolution of high-contrast objects such as metal wire grids is expressed by the modulation transfer function On the other hand the property giving rise to the optimum signal/noise ratio is expressed by the quantum detection efficiency The latter parameter has so far attracted rather scant attention The most comprehensive analyses have been mainly theoretic (STEVELS 1975 STEVELS & PINGAULT 1975 STEVELS & SCHRAMA DE PAUW 1976) If proper phantoms are used for evaluating image quality a shift of interest from the MTF to the quantum detection efficiency and its practical evaluation may be anticipated

SUMMARY

Resolution capacity is traditionally evaluated by radiography of metal objects (lead bar grids or fine slits) These objects yield high image contrast Resolution then is limited by the sideways spread of information as expressed by the MTF However biologic objects of fine dimensions give rise to much less image contrast than the test objects of metal Since the amplitude of the signals thus becomes reduced the signal/noise ratio in fact limits resolution capacity much more effectively than does the sideways spread of information Thus the MTF expresses a property of the radiographic system which appears only rarely to affect the information capacity of clinical radiographic images

ZUSAMMENFASSUNG

Das Auflosungsvermogen wird traditionell durch Rontgenbilder von Metallobjekten (Bleistabchen Gitter oder feine Schlitze) festgestellt Diese Objekte fuhren zu einem hohen Bildkontrast Die Auflosung ist dann begrenzt durch die seitliche Streuung der Information ausgedruckt durch die MTF Biologische Objekte hingegen von feinem Dimension geben Anlass zu wesentlich geringerem Bildkontrast als die Testobjekte von Metall Da die Amplitude der Signale dadurch reduziert wird begrenzt das Signal-Rausch Verhaltnis tatsachlich das Auflosungsvermogen wesentlich effektiver als es die seitliche Streuung der Information tut Daher druckt die MTF eine Eigenschaft des Rontgensystems aus die nur selten die informative Kapazitat des klinischen Rontgenbildes zu beeinflussen scheint

RESUMÉ

Le pouvoir de resolution est traditionnellement évalué par la radiographie d objets métalliques (grille de barres de plomb ou fentes fines) Ces objets donnent un fort contraste d image La résolution est donc limitee par la dispersion laterale de l information exprimee par la FTM Cependant, les objets biologiques de fines dimensions donnent naissance à un contraste d image très inferieur à celui des objets tests en metal Etant donne que l amplitude des signaux est ainsi réduite le rapport signal/bruit limite en fait le pouvoir de resolution de façon beaucoup plus importante que ne le fait la dispersion latérale de l information Ainsi la FTM exprime une proprieté du système radiographique qui n affecte que rarement la capacité d information des images radiographiques cliniques

may then be uncritically applied in human radiology, even by people who would never consider testing the performance of an equipment for chest radiography by using a skeletal phantom. Skeleton and lung tissue need *different optimisation of radiographic procedure* (MATTSSON 1955), as is well known. The present investigation indicates that the same difference applies to clinical radiography in comparison with radiography of metal objects as well. In principle, then, *metal objects should be used for optimisation of radiography of metal objects*. However, they should be avoided in clinical radiography, unless strict precautions are taken to ensure that the special properties of the metal object are considered in the final evaluation.

Estimation of the MTF for intensifying screens is usually based on radiography of a fine metal slit which yields an exposure of extreme contrast. The line spread function and subsequent modulation transfer function thus obtained refer, in a sense, to conditions never actually occurring in clinical radiography. This is not to say that the functions in question should be regarded as irrelevant to the actual spread of light in the screens, yet the relevance of this spread to image quality in the clinical situation remains to be proved. The assumption of MORGAN et coll. (1964) that in general "ability to record detail is poor in those situations where the spread is large and good where it is small" still appears to be considered, by most authors, an axiom in no need of testing. It is only very recently that a test has been published (GRAY et coll. 1978) concerning the value of the MTF in the clinical situation. The authors used a thorax phantom where fine nodules were inserted. Screen film radiography was performed with three different film speeds, so that *noise conditions* were altered without the MTF being affected. The latter factor was also changed by varying the size of the focus. The detection rate for the "coin lesions" caused by the nodules was clearly improved when noise was reduced. Small focus size (i.e. improved MTF) gave no improvement of detection, in fact a slight impairment was noted. These results point in the same direction as those of the present report.

A test object of the kind used here is easy to construct and may be combined with different external attenuating components—air, different contrast media, etc. On top of the phantom various amounts of water can be added, giving rise to secondary radiation to the same extent as is encountered in clinical radiography. Some standard conditions may well be formulated for the evaluation of different kinds of radiographic equipment. For example, equipment designed for full size angiography 35 cm × 35 cm may be tested at a constant amount of water and one or more iodine concentrations. The contrast properties of the final image together with resolution may then be used as an indication of performance for the total equipment.

When the resolution of objects with a small attenuation difference is analysed, the importance of the signal/noise ratio for the limitation of image quality should be expected to increase compared with the sideways diffusion of information as expressed by the modulation transfer function. The decreasing importance of the latter explains the difference between the lead phantom and the other objects exposed. The three intensifying screens used in conjunction with the plexiglass phantom

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FROM THE DEPARTMENT OF RADIOLOGY MEDIZINISCHE AKADEMIE MAGDEBURG DDR —
309 MAGDEBURG GERMAN DEMOCRATIC REPUBLIC

IN VITRO EFFECTS OF CONTRAST MEDIA ON THE WATER CONTENT OF HUMAN ERYTHROCYTES

G BOLLMANN H JÄGER and G FREITAG

In the use of iodized contrast media in the human organism side effects frequently occur Their cause has not yet been clearly elucidated Several hypotheses have been advanced Effects on the nervous system reactions of the cardiovascular system vessel endothelium lesions injuries of blood cell membrane as well as disturbance of water and electrolyte balance have been claimed to be caused by contrast media (BARKE 1970 BECK 1974) Water and electrolyte transfer between the intracellular and extracellular space have been reported to be induced by hyperosmolality of contrast media (CHAPLIN & CARLSSON 1961 GIAMMONA et coll 1963 MEYER & READ 1964 FRIESINGER et coll 1965 MCINTOSH et coll 1967 COHEN et coll 1969 LEVIN et coll 1969) VON BUBNOFF & RIECKER (1961) RIECKER et coll (1963) and FROHLING et coll (1973) stated that blood constitutes a representative model of the water and electrolyte balance and the influence of contrast media was analyzed both in vitro and in vivo particularly the erythrocyte/plasma system Criteria employed to determine disturbances of the water and electrolyte balance induced by contrast media were osmolality (GIAMMONA et coll LEVIN et coll MANN & ZEITLER 1975) hematocrit (SVOBODA & FIALA 1964 a FRIESINGER et coll MCINTOSH et coll LEVIN et coll BJÖRK 1970) hemoglobin content (CHAPLIN & CARLSSON) ion content (LEVIN et coll BECK JAGER 1978) and the morphology of the erythrocytes (CHAPLIN & CARLSSON MEYER & READ SVOBODA & FIALA 1964 b MCINTOSH et coll) Lowering of the hematocrit value increase in hemoglobin content and crenation of erythrocytes after application of contrast media were indirectly considered to indicate decreased water

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REFERENCES

ARNOLD B A EISENBERG H and BJARNGARD B E The LSF and MTF of rare-earth oxysulfide intensifying screens Radiology 121 (1976) 473

ÅSTRAND K and REICHMANN S Optimised tomography Theoretical and practical analyses of the elimination of depiction errors in tomography Acta radiol (1974) Suppl No 338

BÄCKSTRÖM H och LUNDH A Det rontgenfotografiska materialet och dess behandling (In Swedish) In Fotografisk handbok Natur och Kultur Stockholm 1959

DEICHGRABER E REICHMANN S and BURÉN M Film quality in mammary radiography Acta radiol Diagnosis 15 (1974) 93

GRAY J E TAYLOR K W and HOBBS B B Detection accuracy in chest radiography Amer J Roentgenol 131 (1978) 247

MATTSSON O Practical photographic problems in radiography With special reference to high voltage technique Acta radiol (1955) Suppl No 120

MORGAN R H BATES L M GOPALARAO U V and MARINARO A The frequency response characteristics of X ray films and screens Amer J Roentgenol 91 (1964) 476

PERRIN F H The structure of the developed image In The theory of the photographic process Edited by C E K Mees and T H James The Macmillan Company New York 1966

PFEILER M und KUHN H Bedingungen fur die optimale Bildgute in der Koronarserien angiographie Electromedica 41 (1973) 42

REICHMANN S and ÅSTRAND K Influence of radiation dose on image quality Acta radiol Diagnosis 20 (1979) 393

— — and KUNZ G Testing of roentgen film quality Acta radiol Diagnosis 19 (1978) 106

SELIN K and REICHMANN S High density failure of radiographic films Acta radiol Diagnosis 18 (1977) 95

— DEICHGRABER E and REICHMANN S Influence of secondary radiation on image quality Acta radiol Diagnosis 16 (1975) 520

STEVELS A L N New phosphors for X ray screens Medicamundi 20 (1975) 12

— and PINGAULT F BaFCl Eu^{2+} a new phosphor for X ray intensifying screens Philips Res Repts 30 (1975) 277

— and SCHRAMA DE PAUW A D M Theoretical and experimental efficiencies of X ray screens J electrochem Soc 123 (1976) 886

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content in the red blood cells However according to the literature available direct measurements of the cell water content of erythrocytes after contrast media administration have not yet been performed The hematocrit value and the hemoglobin content of erythrocytes permit only rough estimations of the amount of water discharged by the red blood cells Therefore, it was found motivated to examine the erythrocyte water content as a function of the concentration of various contrast media The experiments were carried out in vitro using Visotrast 370 (76% w/v) Adipiodon (50%, w/v) and Dimer X (60% w/v)

Material and Methods

The blood required (5 × 10 ml) was obtained under sterile conditions from cubital veins pressed only during puncture from randomly chosen subjects of either sex The blood samples were taken by means of 10 ml disposable syringes that had previously been wall wetted with a mixture of sodium heparinate solution (SPOFA Prague Czechoslovakia) and isotonic glucose solution at a 1 10 ratio in order to avoid coagulation The blood was immediately transferred into five graduated centrifuge tubes Four of these contained such amounts of contrast media that when blood was added to 10 ml concentrations of 1 10 1 20, 1 50 and 1 100 respectively were obtained Blood and contrast medium were intensively mixed with a glass rod for 2 to 3 min The control blood in the fifth tube was treated identically Immediately afterwards the blood samples were centrifuged at room temperature and 2 500 g for 45 min At this centrifugal acceleration an optimum packing density of erythrocytes is obtained after 30 min (HUMMEL & ZÖLLNER 1957) The plasma supernatant and the top layer of the erythrocyte sediment were drawn off carefully by a water jet pump and discarded A 1 ml pipet was used to collect approximately 1 g erythrocyte sediment from the bottom of each centrifuge tube The sediment was then transferred into a weighing glass and the wet weight was determined on an analytic balance (OWA Labor Type 707 03 VEB Oschatzer Waagenfabrik G D R) Subsequently, the erythrocytes were kept in a drying cabinet at 105 C for 24 hours After cooling down to room temperature in an exsiccator the weight of the dry mass was determined The difference between the wet and the dry weight measurements with the absolute amount of water so obtained being converted into per cent represented the *per cent water content of the erythrocytes*

Results

The mean water content of the erythrocyte sediment was found to be 66 46 ± 1 12% by weight thus being in agreement with data reported in the literature (RIECKER 1957 LOSSI et coll 1960 VON BUBNOFF & RIECKER GESSLER 1961 PRANKERD 1961, HERBINGER 1962 COMAR & BRONNER 1964) Allowing for the plasma error of the erythrocyte sediment which is 2 28 ± 0 44% by volume (RIECKER & VON BUBNOFF

Table 1

Water content of erythrocytes at different concentrations of Visotrast 370

Dilution	N	H_2O before (% by weight)	H_2O after (% by weight)	ΔH_2O (% by weight)	p*
1:10	7	66.33±1.15	59.00±1.44	−7.33	<0.001
1:20	7	66.33±1.15	61.78±2.39	−4.55	<0.001
1:50	7	66.33±1.15	63.23±0.93	−3.10	<0.001
1:100	7	66.33±1.15	65.16±0.79	−1.17	<0.010

N = Number of individual values
* Student's t test (analysis of pairs)

Table 2

Water content of erythrocytes at different concentrations of Dimer X

Dilution	N	H_2O before (% by weight)	H_2O after (% by weight)	ΔH_2O (% by weight)	p*
1:10	15	66.90±1.41	62.87±1.49	−4.03	<0.001
1:20	15	66.90±1.41	64.26±1.48	−2.64	<0.001
1:50	15	66.90±1.41	65.40±1.37	−1.50	<0.001
1:100	15	66.90±1.41	66.24±1.44	−0.67	<0.001

N = Number of individual values
* Student's t test (analysis of pairs)

Table 3

Water content of erythrocytes at different concentrations of Adipiodon

Dilution	N	H_2O before (% by weight)	H_2O after (% by weight)	ΔH_2O (% by weight)	p*
1:10	15	66.07±1.27	68.29±1.42	+2.22	<0.001
1:20	15	66.07±1.27	68.15±1.32	+2.08	<0.001
1:50	15	66.07±1.27	66.45±1.60	+0.38	<0.2
1:100	15	66.07±1.27	65.96±1.1[illegible]	−0.11	>0.2

N = Number of individual values
* Student's t test (analysis of pairs)

1959) the water content observed for the pure erythrocyte mass was 64.18±1.13% by volume which agrees well with the results reported by CZACZKES et coll. (1963) and ELEK & BUKY (1966).

Following the addition of Visotrast 370 and Dimer X to heparinized blood a highly significant decrease in erythrocyte water content occurred depending on the amount of contrast medium added. For the highest concentration (contrast medium/blood = 1:10) the erythrocyte water loss found with Visotrast 370 (Table 1) was 7.33% by

weight which corresponds to some 11 % of the water content For a 1 100 dilution the water loss of the red blood cells induced by the contrast medium was still more than 1 % by weight The respective data for Dimer X (Table 2) were 4 03 and 0 67 % by weight The lesser effect of Dimer X compared to Visotrast 370 is apparently due to its lower osmolality

Unlike Visotrast 370 and Dimer X the addition of Adipiodon to blood (Table 3) at high concentrations caused an uptake of water by the erythrocytes It was only at maximum dilution (1 100) that a slight but insignificant decrease in red blood cell water content was found Moreover the changes in water content were less uniform compared to those obtained for the other two contrast media

Discussion

In view of the fact that the contrast media tested have hyperosmolar properties a water loss i e erythrocyte shrinkage was expected after addition of the three media to the blood However shrinkage of erythrocytes was observed only in the presence of Visotrast 370 and Dimer X while Adipiodon addition to blood resulted in water uptake or swelling of erythrocytes The shrinkage of red blood cells observed with Visotrast 370 and Dimer X is in agreement with findings by CHAPLIN & CARLSSON MEYER & READ SVOBODA & FIALA (1964 a b) MCINTOSH et coll and LEVIN et coll who found a decrease in hematocrit an increase in mean corpuscular hemoglobin concentration enhanced aggregations and agglutinations or crenations of erythrocytes Since both contrast media show only a comparatively poor protein binding capacity and for short periods of action on blood hemolysis is of minor importance (CHAPLIN & CARLSSON SVOBODA & FIALA 1964 a) their hyperosmolality is believed to be the decisive cause of the water loss of erythrocytes

The swelling of erythrocytes following the addition of Adipiodon corresponds with the findings of BERNSTEIN et coll (1964) They found in mongrel dogs after exposure of the blood to Cholografin a considerably reduced or absent sedimentation rate a strongly increased viscosity of the blood and slightly diminished density of the red blood cells at the highest contrast medium concentration used i e 0 86 mg/100 ml (contrast medium/blood = 1 60) By reason of the more difficult packing also observed the authors postulated a decrease in effective density of these red blood cells The swelling demonstrated in the present experiments following the addition of Adipiodon is automatically connected with the decrease in red blood cell density The considerable reduction of erythrocyte diameter with the increased concentration of the contrast medium is however incompatible with this Also the question of the contradiction between diminished sedimentation on the one hand and enhanced aggregation and agglutination on the other hand is still not clear

The erythrocyte swelling after Adipiodon addition despite hyperosmolar properties of the contrast medium is surprising It is known that contrast media with a non substituted hydrogen atom on No 5 carbon atom of the benzene ring are to a great extent bound by plasma proteins in particular albumins (LASSER et coll 1962)

Erythrocytes are also capable of accumulating contrast media on the membrane surface but to an essentially lesser degree Presumably the bond is established by electrostatic attraction between plasma proteins (erythrocytes) and those contrast media When plasma proteins at physiologic blood pH values are assumed to carry positive charges then the bound Adipiodon molecule should have a site of negative charge This site could be a nitrogen atom of the adipoyl diamino group The nitrogen is made positive by the adjacent keto group with the highly negative oxygen atom and consequently the nitrogen to hydrogen bond of the NH grouping is loosened Under favorable environmental conditions the hydrogen may even dissociate as an ion (proton) and be replaced by other substituents In this way proteins can be bound by contrast media containing a hydrogen atom in the 5 position of the benzene ring The hydrogen ions so released cause a decrease in pH The consequence might be an uptake of water i e swelling of the erythrocytes (VON BUBNOFF & RIECKER RIECKER 1963 RADERECHT 1970) But then the acidosis postulated should be substantially greater than the pH decrease measured by MARSHALL & HENDERSON (1968) and LEVIN et coll with Conray 280 and Hypaque M (75 % w/v) since in both contrast media the hydrogen atom is substituted in the 5 position of the benzene ring The present assumption is supported by the fact that—unlike Renografin Hypaque and Miokon—Adipiodon causes a marked agglutination of erythrocytes (LASSER et coll) and has a higher aggregation rate than Urografin and Hypaque (LINDGREN et coll 1964)

On the other hand it may be possible that Adipiodon binding to plasma proteins due to ion inclusion or electrostatic attraction involves diminished ion activity in the plasma with subsequent swelling of the red blood cells A decrease in the particle count of plasma due to aggregation of proteins and erythrocytes by means of Adipiodon should be of lesser importance An acidotic effect of Adipiodon owing to a shift of Donnan s equilibrium has also to be taken into consideration The considerably lower protein binding capacity of contrast media with a substituted hydrogen atom on No 5 carbon atom of the benzene ring could be due to steric reasons If the present assumption were confirmed by the use of labeled substances then the determination of water content would provide a simple method for differentiating between contrast media with and without binding capacity

SUMMARY

The effect of the concentration of the contrast media Visotrast 370 Dimer X and Adipiodon on the water content of human erythrocytes was analysed in vitro While a concentration dependent water discharge (shrinkage) of erythrocytes was found in the presence of Visotrast 370 and Dimer X the application of Adipiodon caused water uptake (swelling) Possible causes of swelling of red blood cells despite the hyperosmolality of Adipiodon are discussed

ZUSAMMENFASSUNG

Unter in vitro Bedingungen wurde der Einfluß der Konzentration der Röntgenkontrastmittel Visotrast 370 Dimer X und Adipiodon auf den Wassergehalt menschlicher Erythro-

zyten untersucht W ihrend es in Gegenwart von Visotrast 370 und Dimer X zu einer konzentrationsabhangigen Wasserabgabe (Schrumpfung) der Erythrozyten kam fuhrte Adipiodon zu einer Aufnahme von Wasser (Schwellung) Mogliche Ursachen der Schwellung der roten Blutzellen trotz Hyperosmolalit it des Adipiodon werden diskutiert

RESUME

L effet de la concentration des moyens de contraste Visotrast 370 Dimer X et Adipiodon sur la teneur en eau des érythrocytes humains a été étudié in vitro Alors qu en présence de Visotrast 370 et de Dimer X les érythrocytes subissent une perte d eau dépendant de la concentration (diminution de volume) L application d Adipiodon cause une absorption d eau (gonflement) Les auteurs examinent les causes possibles de l augmentation de volume des globules rouges sanguins malgré l hyperosmolalité de l Adipiodon

REFERENCES

BARKE R Rontgenkontrastmittel Chemie Physiologie Klinik Georg Thieme Leipzig 1970

BECK J P Der Einfluß des Rontgenkontrastmittels Visotrast 370 auf den Elektrolytgehalt den Wassergehalt und das Einzelvolumen menschlicher Erythrozyten unter in vitro-Bedingungen Diploma Thesis Medizinische Akademie Magdeburg 1974

BERNSTEIN E F EVANS R L and SALTZMAN G F Physico chemical properties of blood following exposure to methylglucamine iodipamide and other contrast media Acta radiol Diagnosis 2 (1964) 401

BJÖRK L Effect on erythrocytes of large doses of contrast medium in clinical angiocardiography Acta radiol Diagnosis 10 (1970) 151

BUBNOFF M VON und RIECKER G Zellosmolaritat und Zellwassergehalt Klinische und experimentelle Untersuchungen an Erythrozyten Klin Wschr 39 (1961) 724

CHAPLIN H and CARLSSON E Changes in human red blood cells during in vitro exposure to several roentgenologic contrast media Amer J Roentgenol 86 (1961) 1127

COHEN L S KOKKO J P and WILLIAMS W H Hemolysis and hemoglobinuria following angiography Radiology 92 (1969) 329

COMAR C L and BRONNER F Mineral metabolism and advanced treatise Vol II Part A p 144 Academic Press New York and London 1964

CZACZKES J W ULLMANN TH D ULLMANN L and BAR KOCHBA Z Determination of the red blood cell content of water sodium and potassium in normal subjects J Lab clin Med 61 (1963) 873

ELEK JR S und BUKY P Zur Bestimmung des Kalium Natrium Magnesium und Wassergehaltes der Erythrozyten Folia haemat 86 (1966) 215

FRIESINGER G C SCHAFFER J CRILEY J M GAERTNER R A and ROSS R S Hemodynamic consequences of the injection of radiopaque material Circulation 31 (1965) 730

FRÖHLING P LEMKE E und METZ E G Methodische Probleme bei der Bestimmung der intrazellul iren Elektrolyte in der chemischen Praxis Z med Labortechnik 14 (1973) 302

GESSLER U Intra und extrazellulare Elektrolytveranderungen bei metabolischer Azidose Untersuchungen an Erythrozyten Klin Wschr 39 (1961) 232

GIAMMONA S T LURIE P R and SEGAR W E Hypertonicity following selective angiocardiography Circulation 28 (1963) 1096

HERBINGER W Über die Methode der Kalium Natrium und Wasserbestimmung in den Erythrozyten Ärztl Labor (1962) 269

HUMMEL H und ZÖLLNER R. Über den Einfluß unterschiedlicher Zentrifugierbedingungen auf die Größe des Porenvolumens bei Sedimentation menschlicher Erythrozyten Z ges exp Med 129 (1957) 250
JAGER B Zur Beeinflussung des Wassergehalts der Erythrozyten und des Ionengleichgewichtes von Natrium Kalium und Kalzium zwischen Plasma und Erythrozyten durch verschiedene Kontrastmittel unter in vitro-Bedingungen M D Thesis Medizinische Akademie Magdeburg 1978
LASSER E C FARR R E FUJIMAGARI T and TRIPP W N The significance of protein binding of contrast media in roentgen diagnosis Amer J Roentgenol 87 (1962) 338
LEVIN A R GROSSMAN H SCHUBERT E T WINCHESTER P and GILLADOGA A Effect of angiocardiography on fluid and electrolyte balance Amer J Roentgenol 105 (1969) 777
LINDGREN P LÖFSTRÖM B and SALTZMAN G F Intravascular erythrocyte aggregation after intravenous injection of contrast media Acta radiol Diagnosis 2 (1964) 334
LOSSE H WEHMEYER H und WESSELS F Der Wasser und Elektrolytgehalt von Erythrozyten bei arterieller Hypertonie Klin Wschr 38 (1960) 393
MANN S und ZEITLER E Verhalten der Serumosmolarität bei hohen Kontrastmitteldosen im Rahmen der Angiographie Fortschr Röntgenstr 122 (1975) 135
MARSHALL M and HENDERSON G A Tendency to acidosis following injection of radiopaque contrast material Brit J Radiol 41 (1968) 190
MCINTOSH H D HURST V W THOMPSON JR H K MORRIS JR J J and WHALEN R E The hemodynamic effects of the injection of contrast media (Isopaque) Angiology 18 (1967) 306
MEYER M W and READ R C Red cell aggregation from concentrated saline and angiographic media Radiology 82 (1964) 630
PRANKERD T A J The red cell Blackwell Scientific Publications Oxford 1961
RADERECHT H J Übersicht Stoffwechsel der Blutzellen und seine Beeinflussung unter Konservierungsbedingungen Folia haemat 93 (1970) 117
RIECKER G Über den intrazellulären Wasser und Elektrolytstoffwechsel Untersuchungen an Erythrozyten 1 Mitteilung Methodik Trink und Durstversuche Salzentzug und Salzzufuhr Klin Wschr 35 (1957) 1158
— Kationenverteilung an Erythrozyten bei Azidose Klin Wschr 41 (1963) 184
— und BUBNOFF M VON Über den intrazellulären Wasser und Elektrolytstoffwechsel Untersuchungen an Erythrozyten 2 Mitteilung Ödemkrankheiten Klin Wschr 36 (1958) 556
— — Die interzelluläre Plasmamenge im Erythrozytensediment Z ges exp Med 132 (1959) 102
— GURLAND H J EDEL H BOLTE U D EIGLER J RENNER E und BUCHBORN E Neue Methoden zur Erkennung von Störungen der intrazellulären Wasser und Elektrolytverteilung bei Niereninsuffizienz Verh dtsch Ges inn Med 69 (1963) 707
SVOBODA M und FIALA J (a) Einfluss jodierter wasserlöslicher Kontrastmittel auf die roten Blutkörperchen im Verlauf der Kontrastuntersuchungen Radiol diagn 5 (1964) 207
— — (b) Morphologische Veränderungen der roten Blutkörperchen nach verschiedenen wasserlöslichen jodhaltigen Röntgenkontrastmitteln Radiologe 4 (1964) 404

Book review

PEDIATRIC ONCOLOGIC RADIOLOGY Edited by Bruce A Parker and Ronald A Castellino 451 pages C V Mosby Company Saint Louis 1977 Price US $39 50

Current advances in pediatric oncology are based on intimate teamwork utilizing new forms of combined treatment which can be individually adapted to the nature of the disease and be modified according to its course This has become possible thanks to progress made in diagnosis and has resulted in a substantial increase in the survival of infants and children with malignant diseases This has in turn placed new demands on diagnosis It is not only important to identify the malignancy early and to define its site stage and extension it is also essential to supervise its response to the treatment to detect any recurrence without unnecessary delay and to recognize any complication of the disease or the treatment

Radiology plays an important role in all these respects However the pediatric radiologist in an oncologic team should preferably not only master his own specialty but also possess sufficient knowledge of other diagnostic procedures and tests to integrate all the findings with clinical management The book edited by Parker and Castellino offers great help in the acquirement of such knowledge

An introductory survey of pediatric oncology by Wilbur is followed by a section on the pediatric application of special procedures angiography (Fellows) neuroradiology (Gooding) lymphography (Castellino et coll) nuclear medicine (Gilday) and echography (Filly) Subsequent sections are concerned with the systematic description of the main pediatric neoplasms leukemia (Gwinn) Hodgkin s disease (Parker & Castellino) non Hodgkin s lymphoma (Castellino & Parker) histiocytosis X (Kirks & Taybi) Wilms tumor (Grossman) neuroblastoma and other adrenal neoplasms (Friedland & Crowe) primary tumors of the liver (Wallace) of the central nervous system (Gooding) of bone (Steinbach & Parker) and rhabdomyosarcoma (Lee) These sections deal mainly with the radiologic and pararadiologic findings and their evaluation but also with pathology clinical presentation pertinent laboratory tests classification (or staging) treatment and prognosis

A large number of highly informative roentgenograms are reproduced The illustrations include some isotope scans and echographic findings

Georg Theander

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CONTRAST ENHANCEMENT WITH TIME IN GLIOMAS

Stereotactic computer tomography following contrast medium infusion

R LEWANDER

The time course of enhancement in brain lesions at computer tomography (CT) during the first 3 hours after intravenous bolus injection of contrast medium was analysed from the differential diagnostic point of view by HATAM et coll (1975) An extension of this report in a larger series of patients was presented by LEWANDER et coll (1978 a) to elucidate whether enhancement dynamics recorded during 60 min alternatively 30 min might be sufficient for the same purpose It was concluded that the indicated time span was still most useful in the differential diagnosis of intra cranial lesions Al a observation times of 30 to 60 min were found to constitute the upper limits of what could be achieved without resort to special head fixation facilities In particular repeat measurements of satisfactory reproducibility put high demand on a reliable head fixation The drawbacks of conventional administration of contrast medium injected as a bolus for obtaining enhancement were also pointed out i e detrimental variations of injection rate and recirculation

An attempt has been made to eliminate these inconveniences by using a head fixation system of new design and a two component system of administration of contrast medium injected in the form of a bolus immediately followed by an infusion

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to provide a constant concentration level of medium in the blood during the examination. Using a stereotactic technique BOËTHIUS et coll (1978) and LEWANDER et coll (1978 b) found that it was possible to predict the tumour type of biopsy specimens from the enhanced CT image with a certain degree of confidence. They also found that it was necessary to obtain biopsies from several parts of the tumour in order to *obtain a specific diagnosis*

The aim of the present investigation was to find out if different tumour components and contiguous tissues (microscopically confirmed) have different dynamic enhancement response after contrast medium infusion. *The results of an attempt to define enhancement characteristics of gliomas of different grades are also presented*

Material and Methods

The material consisted of 14 patients with intracranial glioma aged between 33 and 70 years. The diagnosis was established on the basis of microscopic and cytologic examinations (stereotactic biopsies) in 13 cases and at autopsy in one case. The patients were referred to the neuroradiologic department for a stereotactic CT examination where the coordinates of the target points assessed at the CT image were transferred to those of the stereotactic system used for biopsy. Most patients were included in a previous report discussing the results of stereotactic biopsy in patients with glioma (LEWANDER et coll 1978 b). From this original material 5 patients had to be excluded because of the following reasons. In one patient the periphery of the lesion was rigid and therefore attempts to obtain usable samples from this part failed and no diagnosis was established. In one patient the tumour was undifferentiated and impossible to classify. In one case from which a perfect biopsy sample was obtained no tumour cells could be identified, a reactive gliosis or *alternatively an astrocytoma grade I was suggested. However* this patient had an intracerebral subcortical haematoma in the right parieto occipital region one year previously which was evacuated operatively. Then an acute left central paralysis of *the seventh nerve and a left hemiparesis developed. CT 25 days later* revealed an expanding lesion in the right hypothalamus with a faint rim appearing after contrast enhancement. At a repeat CT 36 days later the lesion was found to be less expanding. Carotid angiography demonstrated a slow circulation but no evidence of tumour. The history, development of the disorder, findings at CT, carotid angiography and microscopy and the fact that enhanced rims are not consistent with astrocytomas of grade I (TCHANG et coll 1977, LEWANDER et coll 1978 b) all make a vascular lesion the most plausible diagnosis. Finally 2 patients not fulfilling the protocol criteria were excluded. A helmet made of a band of thermoplast was applied around the patient's head for obtaining a reliable skull fixation (BERGSTRÖM & GREITZ 1976, LEKSELL et coll 1976, LEWANDER et coll 1978 b). An EMI Mark I CT scanner was used with the 0.8 cm collimator in 12 cases and the 1.3 cm one in 2 cases. In 2 cases additional sections in the target plane were performed with an 0.33

Fig. 1 Glioma of corpus callosum Positioning difficulties of ROI Biopsy target points indicated (a) with ROI in corresponding points consisting of 9 pixels (b) and ROI of sufficient size to avoid too great statistical fluctuations (c) Centre of target 2 had to be moved 3 pixels posteriorly and 3 pixels to the right in order not to include region of low attenuation (necrosis)

cm collimator Contrast medium enhancement was achieved by an intravenous bolus injection (1 ml Isopaque Cerebral/kg body weight) followed by a drip infusion of the same medium during 13 to 50 min (0 02 ml/min/kg body weight) This procedure yields an almost constant blood concentration during the examination (BERGSTRÖM personal communication) The CT section of the central part of the tumour was selected so as to obtain samples from both enhanced and unenhanced parts of the tumour and in addition from the peripheral zone of low attenuation Using this method it was possible to obtain up to 5 separate samples from one tumour producing only one insertion track in one and the same CT slice This section was scanned 2 to 3 times during the contrast medium infusion and the time elapsed after the bolus injection was recorded With guidance of the CT image regions of interest (ROI) were outlined having their centre in the biopsy target point and with a shape that fitted best to the structure to be examined

The regions of interest were made as large as possible and still within the area of tissue with a CT appearance identical to that of the biopsy target point (Fig 1) In 9 cases the centre of the ROI was moved from the target point up to 5 pixels—within the same structure in the CT image—to obtain a larger area A computer program designed by BERGSTRÖM & SUNDMAN (1976) was used for calculating the mean attenuation coefficient and the standard deviation of a given region—elliptic or rectangular with the orientation varied as required This program could be introduced by the computer into all images in a time sequence even with several overlapping regions in each image (LEWANDER et coll 1978a) The original EMI scale of ± 500 attenuation units (u) from water level has been used throughout

Fig 2 CT image of a central astrocytoma of grade III with anterior biopsy target indicated (→)

The enhancement characteristics for each biopsy have been described as linear functions of time

Biopsy technique In 12 patients the same biopsy technique was applied as that reported previously (BOLTHIUS et coll, LEWANDER et coll 1978 b) In 2 patients a new spiral needle extending 50 mm into the tumour was used The technique was adopted in order to make possible an exact point to point comparison between the microscopic appearance of the biopsy specimen and the corresponding CT image (Figs 2 3)

Results and Discussion

Normal brain tissue The enhancement response in apparently normal brain tissue after intravenous bolus injection followed by drip infusion of contrast medium is presented in Fig 4 The curve is drawn on time interpolations from measurements in 9 patients The mean attenuation value before contrast medium administration was 17 7 u SD = 1 5 SE = 0 5 The mean enhancement was 0 8 u and varied within a range of 0 7 u Since the enhancement of blood is about 13 u (BERGSTRÖM & ERICSON 1979) this would correspond to a blood volume of 6 per cent (0 8 × 100/13 = 6 %) The criterion of normality in these cases was the appearance at CT The ROI was chosen in the hemisphere not involved by the lesion Such apparently normal regions of the brain cannot be regarded as normal in a strict sense since

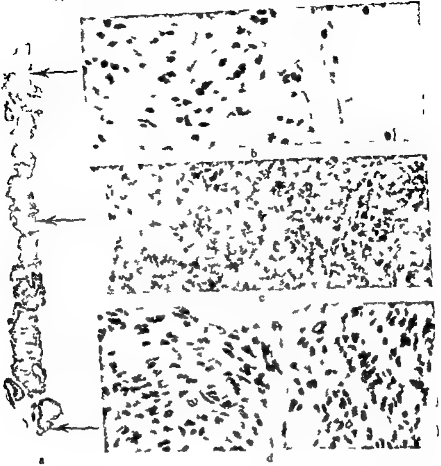
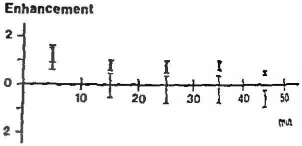


Fig 3 a) Biopsy sample obtained with a spiral needle extending 50 mm into tumour b) preparations from corresponding parts of biopsy sample as indicated with arrows Upp r row Anterior tumour border (normal brain tissue to the right) Middl row Necrosis Lower row Astrocytoma grade III

mass effects and altered circulation might influence the tissues at a considerable distance from the lesion The ROI was positioned to include both grey and white matter since reliable separation *in the images* was not possible The results confirm previously pushshed data (LEWANDER *et coll* 1978 a BERGSTROM & ERICSO ı) Corrections for scan level (LEWANDER *et coll* 1978 a) have not been p rformed since this material is not to b considered normal in a sci ntific s nse and b caus the plastic helmet might have a *faint influence* on the attenuation values

Edema The enhancement response of edematous tissue appears in Fig 4 The curve represents time interpolations from *measurements* in 5 patients The mean attenuation value before contrast medium administration was 15 1 u SD=3 1

Fig 4 Enhancement response of apparently normal brain tissue (thick columns) and edema (thin columns) after intravenous bolus injection followed by drip infusion of contrast medium Measurements from 9 and 5 patients respectively interpolated in time and normalized to zero (I = ±1 SE) Mean attenuation value before contrast medium administration 17 7 u (SD = 1 5) and 15 1 u (SD 3 1) respectively



SE = 1 4 and the enhancement varied within a range of 1 7 u The curve and the mean attenuation value before administration of contrast medium both differed from those reported previously (LEWANDER et coll 1978 a) This discrepancy in the results should reflect the influence of statistical variations and the fact that the series referred to (LEWANDER et coll 1978 a) consisted of only 3 cases of astrocytoma mixed up with 2 ependymomas, 1 abscess 1 haematoma and 1 metastasis The latter part of the group had highly varying degree of edema In addition in one patient the attenuation value recorded before contrast administration was unusually high probably being the result of movement artifacts The enhancement values were negative which distort the mean values in Fig 4 Therefore, no certain conclusions have been drawn concerning the enhancement of the edematous tissue in this group of patients

Astrocytoma grade III to IV This group comprised 11 astrocytomas Biopsies and ROI from 2 different parts of the rim were examined in 2 tumours with typical enhanced rims In one tumour with 2 enhanced foci biopsies and ROI from each focus were examined as well (Fig 5) The enhancement response of these 3 cases appears in Fig 6 It would be expected that the curves from virtually identical components in the CT image should be essentially the same However, the enhancement differs within a range of 1 3 u in the beginning and up to 2 7 u at the end of the examination This could be due to biologic/physical or technical reasons Especially in tumour tissue the cell density, vascularity and edema can vary considerably The microscopic appearances of the specimens of these cases have therefore been checked with regard to differences concerning these properties No reliable correlation between the factors mentioned and the appearances of the curves could be established The statistical variations of the measurements might explain the whole difference in enhancement response of these cases since random noise will introduce an inaccuracy in the single determination within the range of about 1 u Artifacts such as movements of the skull and partial volume effects can be of the same magnitude For these reasons the mean value of the curves in these 3 cases has been used when presenting the enhancement response of the 11 astrocytomas grade III to IV in the material (Fig 7)

a b c

Fig 5 3 cases (2 7 13) where 2 biopsies and 2 ROI from different parts of the same tumour component have been examined a) Anterior and posterior part of rim (Case 2) b) Anterior and posterior part of rim (Case 7) c) Anterior and posterior part of 2 tumour foci (Case 13)

A considerable variation both in the immediate and in the dynamic characteristics of enhancement is found An enhancement curve drawn as in Fig 4 from measurements of the 7 patients in this group examined before contrast medium administration appears in Fig 8 Initial mean enhancement response was 9 1 u with a slow decrease within a range of 3 5 u during 45 min The mean attenuation value before contrast medium administration was 16 4 u SD=2 0 SE=0 8 (The slope of the curve is discussed in the General discussion)

In 4 cases of this group of astrocytoma areas of low attenuation but nevertheless with viable tumour cells were found (Fig 9 3 6 8 13) These areas generally had no or only subtle enhancement and had a mean attenuation value of 16 8 u before contrast medium administration not differing from that of normal brain tissue However in one case (No 3) the attenuation values were high and exceeded 25 u probably due to a partial volume effect and a slight patient movement (Fig 10) The enhancement in 4 cases of tumour necrosis are shown in Fig 9 1 2 9 14 They form a rather homogeneous group with no significant enhancement and varying within the range of 4 u with a mean attenuation value of 11 5 u before contrast medium administration The attenuation values exceed that of cyst liquid (Fig 9 7) but the material is too small to allow reliable conclusions

Astrocytoma grade I to II The enhancement in 3 astrocytomas of this type is presented in Fig 11 No or only a faint response after contrast medium administration occurred Measurements from the same patients interpolated in time and normalized to zero are given in Fig 8 The mean attenuation value before administration of contrast medium was 15 7 SD=3 8 SE=2 2 During 45 min an unspecific variation

Fig 6 Enhancement response in high attenuating part of 3 astrocytomas of grade III after contrast medium bolus injection followed by infusion Values before contrast administration represented by horizontal line 2 biopsies from different parts of the same tumour component have been taken (cf Fig 5) Thick line represents anterior and thin line posterior part of the same tumour

Fig 7 Enhancement response in high attenuating parts of 11 astrocytomas of grade III to IV illustrated as in Fig 6

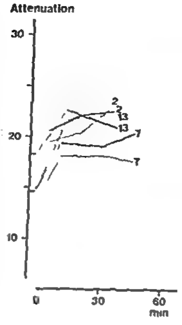


Fig 6

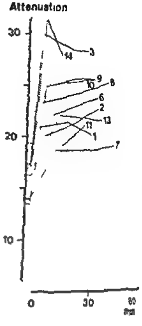


Fig 7

within the range of less than 1 u occurred This finding confirms previous results (TCHANG et coll · BUTLER et coll 1978 LEWANDER et coll 1978 a b)

General discussion

Examination technique The main practical problems met with in sequential CT are patient movement and difficulties in obtaining reproducible repeat scans (HATAM et coll LEWANDER et coll 1978 a) In this series a plastic helmet was applied on all patients in order to reduce movement thereby allowing repeat examinations and stereotactic procedures It is true that a helmet would not be as effective as screws otherwise used in most stereotactic techniques This would particularly apply with a flat occiput a straight transition from the frontal to the nasal bone and an unusually movable scalp Also with a helmet movements up to 2 mm in the tomographic plane and up to 3 mm perpendicular to the plane has been recorded (BERGSTRÖM) (Fig 10) Another disadvantage is the discomfort caused by the helmet Thermoplast invariably shrinks when it hardens and therefore may give rise to pressure symptoms such as headache and vomiting Screws driven into the calvarium should provide for a better fixation of the head However this method should render repeat examinations difficult Artifacts from the screws in the CT image may involve difficulties in evaluating the images The last two factors turnerd the weight of balance in favour of the helmet

CT image Errors that can be referred to the CT image or to the transformation of coordinates from the CT image to the operation device have been discussed previously (LEWANDER et coll 1978 b)

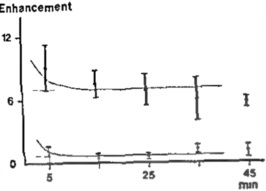


Fig 8 Enhancement response in 7 astrocytomas of grade III to IV (thick columns) and 3 astrocytomas of grade II (thin columns) after contrast medium administration Measurements interpolated in time and normalized to zero (I = ±1 SE) Mean attenuation value before contrast medium administration 16 4 H (SD = 2 0) and 15 7 H (SD = 3 8) respectively

Localization of ROI In the first attempt to evaluate the dynamic characteristics of the different components of the tumours small ROI (9 pixels) were made with the centre in each target point However using a region consisting of only 9 pixels great statistical fluctuations are to be expected and in fact the standard deviations were higher than could be accepted In addition small ROI are relatively sensitive to even minor patient movements (1–3 mm) which applies particularly to those regions lying near a tissue with quite a different attenuation number (Fig 10) Finally with small ROI many of the targets were placed in what was predicted and found to be borders between two different components Due to these disadvantages the whole material was revised and larger ROI were outlined (Fig 1) The attempt has been to make them as large as possible and still within an area having the same appearance at CT as that of the biopsy target point The target point invariably was contained within the ROI although it often had an eccentric location due to the wish to obtain representative tissue samples from the specimens of one single biopsy track The shift of the ROI out of the centre of the target point usually amounted to 1 to 2 pixels in one exceptional case the shift was 5 pixels Targets that were located at the border between different tissues were omitted

Biopsy technique A new technique was introduced tentatively A spiral needle was designed to enable 50 mm long specimens of the tumour tissue to be obtained The intention was to analyse the mode of growth of gliomas and to make a detailed comparison between the microscopic appearances of the tumour and the corresponding CT image The attempts were not successful in that specimens of the suggested length could not be obtained The reasons are probably the following Mechanical compression of the tumour tissue at the biopsy necrosis or fluid present in the centre of the tumour makes the spiral not moving properly into the lesion during the screwing procedure and shrinkage of the specimen during the microscopic preparation

All three factors cause a shortening of the specimen rendering it difficult to make a point to point comparison The needle was used in only 2 cases in this group

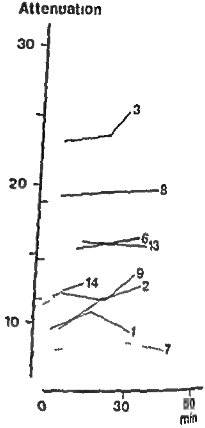
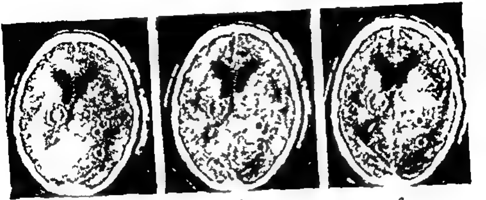


Fig. 9. Enhancement response of a cystic component (7), regions of necrosis (1, 2, 9, 14) and regions of low attenuation (3, 6, 8, 13) in 4 astrocytomas of grade III to IV (cf. Fig. 7)

Samples of 35 and 25 mm in length were obtained. The method was abandoned and the remainder of the cases all were examined with the original technique giving multiple 10 mm long samples of tissue.

The influence of steroids on contrast medium enhancement. Steroids seem to affect the permeability of brain tissue cellular membranes by providing a protective effect on the blood brain barrier (LASTER et coll. 1978). These authors found that the rim of enhancement appearing after contrast medium administration in early stages of an intracerebral haematoma could be modified with steroids. DEMOPOULOS et coll. (1973) were of the opinion that the protective effect can be related to intercalation of steroids into the archways created by the fatty acid tails of membrane phospholipids. This was clinically demonstrated by CROCKER et coll. (1976) who reported on the effect of dexamethasone on the accumulation of meglumine iothalamate and $^{99}Tc^{m}$ pertechnetate in brain tumours on both CT and nuclide brain scans.

In the present series all patients but 2 were given different types of steroids. The latter cases were astrocytomas of grade II (Fig. 11, 5, 12) and only slight or no enhancement at all occurred. Thus all cases with enhancing tumours have been treated with steroids and should be regarded essentially equal from this point of view.



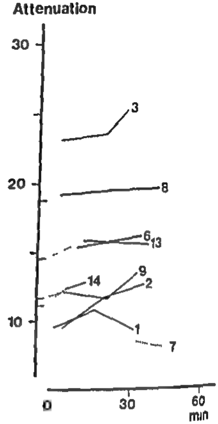
a b c

d

Fig. 10. Astrocytoma of grade III. a) Before, b) during administration of contrast medium at 3 min, c) at [illegible]0 min, d) at [illegible]8 min. Even small movements influence on the enhancement response curves (ROI = centre of tumour, last measurement, cf. Fig. 9.3)

Blood brain barrier break down: Previously (LEWANDER et coll. 1978 a) a three compartment model was introduced to explain the mode of enhancement in intracranial lesions after contrast medium injection. Such a model will serve more as a means of characterizing the mode of enhancement by a few parameters than to explain the underlying mechanisms. The model includes one vascular compartment and two extravascular compartments, one to which the contrast medium passes rapidly and one to which the passage is slow. The morphologic correlates to the postulated extravascular compartments may be assumed to range from extracellular or CSF spaces to different cell populations within various lesions, intra- or extracerebral, but no conclusions as to their nature are warranted from the present results.

This small material does not allow an analysis of the mode of enhancement using a mathematical formulation of the compartment model. However, some implications of the model may be discussed. A technique with a combined bolus and infusion administration of contrast medium results in a high initial iodine concentration in the blood followed by a rapid decrease to a constant level (BERGSTRÖM). The high initial blood values may have affected the attenuation values obtained at the first



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contribute much to the enhancement Astrocytomas of grade I to II have a minimum enhancement (mean value 0 7 u) with no significant increase during the examination This means that the combined effect of the vascular and the fast compartments is in the order of 5 per cent ($0.7 \times 100/13 = 5$%, cf Fig 8) The contribution from the slow extravascular compartment seems also to be small during the rather short examination time Measurements made during extended examinations may reveal enhancement in which the influence from the slow extravascular compartment will be evident In conclusion it seems to be possible to differentiate astrocytomas of grade I to II from the much more malignant lesions of grade III to IV by means of enhancement

Much interest is today centered around the differential diagnosis of gliomas versus brain infarctions The dynamic enhancement characteristics of the latter lesions on CT following the same type of contrast medium administration as in the present series have been reported by BERGSTRÖM & ERICSON The characteristics were analysed on the basis of a compartment model They found that factors like alterations in regional blood volume and contrast medium in the extravascular space affect different parts of the infarct to a varying degree A rapid and a slow component of the enhancement could be quantified and it was suggested that both of them should mainly be due to extravascular contrast medium Since the dynamic enhancement in high attenuating parts of infarctions is quite different from that of gliomas a new way to a more reliable diagnosis seems to be opened

SUMMARY

Dynamic enhancement of astrocytomas has been investigated with CT following infusion of contrast medium The areas of measurement corresponded with obtained stereotactic biopsies The resulting types of enhancement are discussed in terms of a 3-compartment model Great differences exist in the degree of enhancement of astrocytomas of grade I to II and those of grade III to IV In the latter tumours a dynamic response appears to occur distinctly different from that in infarctions

ZUSAMMENFASSUNG

Die dynamische Kontrastverstarkung von Astrocytomen wurde mit Hilfe von Computertomographie im Anschluss an eine Infusion von Kontrastmittel untersucht Die Messungsgebiete entsprachen denen wo die stereotaktischen Biopsien genommen wurden Die erhaltenen Typen von Verstarkung werden in Termen eines 3 Kompartment Modells diskutiert Grosse Unterschiede im Grad der Kontrastverstarkung von Astrocytomen Grad I bis II und solchen von Grad III bis IV wurden gefunden Bei den letzteren Tumoren schien eine dynamische Antwort aufzutreten die sich klar von derjenigen bei Infarzierung unterscheidet

RÉSUME

Le renforcement dynamique de la densité des astrocytomes a ete etudie par la tomodensitometrie après injection de moyen de contraste Les regions ou la densite a ete mesuree ont

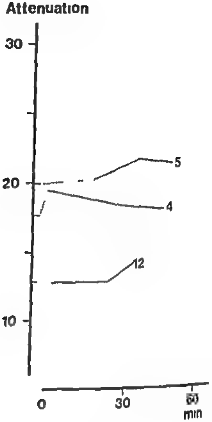

Fig 11 Enhancement response of 3 astrocytomas of grade I to II illustrated as in Fig 6

measurement of the high enhancement regions of astrocytomas of grade III to IV (Fig 8) These facts will explain the subsequent descent of the enhancement curve It is suggested that the following parts of the curve are at a constant level taking the standard errors of determination into consideration The attenuation values present at 45 min refer to 2 cases only why the statistical inaccuracy is fairly large in this phase of the examination Obviously the slow extravascular compartment plays an insignificant role for the high enhancing components of astrocytomas III to IV during the chosen time of examination since a slow increase of the enhancement would otherwise have been recorded Thus the characteristics of the enhancement curve (Fig 8) seem to reflect the vascular and the fast extravascular compartments only Since the enhancement of blood following the same mode of contrast medium administration as in the present series is about 13 u (BERGSTRÖM & ERICSON) and the mean enhancement of the astrocytomas of grade III to IV is approximately 7 u the vascularity of the lesion would have to be 50 to 60 per cent (7 × 100/13 54% cf Fig 8) had the extravascular compartment been the only factor of significance However this is most unlikely not least in view of the microscopic appearance of the tumours Consequently the fast extravascular compartment should be considered to be the most important factor The suggested mechanism is that the substances passing the injured barrier may result in an increased iodine concentration in the extravascular space The size of this compartment need not be very large but still

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY RIKSHOSPITALET OSLO NORWAY

ARTERIAL STRUCTURES OF THE CHEST AND ABDOMEN AT COMPUTER TOMOGRAPHY

A KOLBENSTVEDT F KOLMANNSKOG and T AAKHUS

A thorough knowledge of the anatomy of transverse sections of the body is a prerequisite for correct evaluation of examinations by computer tomography Arterial and venous structures appear in every section They are often easily recognised but abnormalities or anomalies may cause difficulties in the analysis of the images A description of venous structures in transverse sections was given previously (KOLBENSTVEDT et coll 1979) The purpose of the present report is to describe the appearances of normal and abnormal arterial structures as demonstrated at computer tomography of the thoracic and abdominal regions

A Delta Scan 50 FS with a scan time of 18 s was *employed* *Further* details about technique and m thod were given previously (KOLBENSTVEDT et coll) *The illustrations* of the pres nt report are s lected from a total of 1 440 examinations of the abdomen and 370 of the chest p rformed during the period from September 1977 to Novemb r 1978

Arteries of the chest

Calcified aortic valves may be identified in sections through the heart (KREEL 1977) In the present series artifacts due to cardiac movements caused impaired image quality in sections with valvular calcifications The aortic arch (Fig 1) appeared as a curved structure running to the left of the trachea and the oesophagus from the right anterior aspect of the mediastinum to the left posterior one The convex margin faced forwards and towards the left A case with aneurysmal dilatation of the aortic arch is illustrated in Fig 2

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correspondu avec des biopsies stéréotaxiques Les types de renforcement de densité sont étudiés par un modèle tricompartimental Il y a des grandes différences dans le degré d'atténuation des astrocytomes de grade I a II et de grade III à IV Dans ces dernières tumeurs, il paraît y avoir une reponse dynamique qui est nettement différente de celle qu on trouve dans les ramollissements

REFERENCES

Bergström M Personal communication (1978)
— and Ericson K Compartment analysis of contrast enhancement in brain infarctions To be published in J Comp Ass Tomogr
— and Greitz T Stereotaxic computed tomography Amer J Roentgenol 127 (1976) 167
— and Sundman R Analysis of regions of interest in EMI scans Brit J Radiol 49 (1976) 549
Boethius J Collins V P Edner G Lewander R and Zajicek J Stereotactic biopsies and computer tomography in gliomas Acta neurochir 40 (1978) 223
Butler A Horii S Kricheff I Shannon M and Budzilovish G Computed tomography in astrocytomas Radiology 129 (1978) 433
Crocker E Zimmerman R Phelps M and Kuhl D The effect of dexamethasone upon the accumulation of meglumine iothalamate and technetium pertechnetate in cerebral tumours as determined by computed tomography J nucl Med 17 (1976) 578
Demopoulos H Milvy P Kakari S and Ransohoff J Molecular aspects of membrane structures in cerebral edema *In* Steroid and brain edema p 29 Edited by H Reulen and K Schurmann Springer Berlin Heidelberg New York 1973
Hatam A Bergvall U Lewander R Larsson S and Lind M Contrast medium enhancement with time in computer tomography Acta radiol (1975) Suppl No 346 p 63
Laster D W Moody D and Ball M Resolving intracerebral hematoma Alteration of the Ring sign with steroids Amer J Roentgenol 130 (1978) 935
Leksell L A stereotaxic apparatus for intracerebral surgery Acta chir scand 99 (1949) 229
— The stereotaxic method and radiosurgery of the brain Acta chir scand 102 (1951) 316
— Some principles and technical aspects of stereotaxic surgery *In* Pain p 493 Little Brown and Company Boston 1966
— (a) A note on the treatment of acoustic tumours Acta chir scand 137 (1971) 763
— (b) Stereotaxis and radiosurgery Charles C Thomas Springfield Ill 1971
Lewander R Bergström M and Bergvall U (a) Contrast enhancement of cranial lesions in computed tomography Acta radiol Diagnosis 19 (1978) 529
— Boethius J Collins V P Edner G Greitz T and Willems J (b) Stereotactic computer tomography for biopsy of gliomas Acta radiol Diagnosis 19 (1978) 867
Tchang S Scotti G Terbrugge K Melançon D Bélanger G Milner C and Ethier R Computerized tomography as a possible aid to histological grading of supratentorial gliomas J Neurosurg 46 (1977) 735

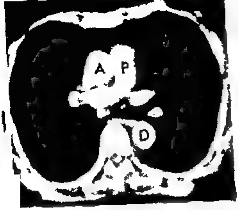


Fig. 4

Fig 5

Fig 6

Fig 4 Section slightly below the tracheal bifurcation A = Ascending and D = Descending aorta Main pulmonary artery (P) to the left of the ascending aorta the right pulmonary artery curves behind it

Fig 5 Patient with a right sided aorta Aortic arch crossing posteriorly to the right of the trachea

Fig 6 Abdominal aorta is indistinguishable due to infiltration of periaortic fat by metastases from testicular neoplasm

line (Figs 9 11 14) In patients with neoplastic involvement of the retrocrural lymph nodes the periaortic fat space could be obliterated and the aorta indistinguishable unless calcified or enhanced by contrast medium

Arteries of the abdomen

The abdominal aorta appeared as a prominent round prevertebral structure in every section above the bifurcation The iliac arteries were less readily distinguishable due to a more tortuous course and surrounding veins and lymph nodes of equal size

The aorta was normally surrounded by fat in the retroperitoneal space In pathologic conditions the periaortic fat could be infiltrated (*Fig 6*) and the contour of the aorta therefore invisible Periaortic hematoma following surgery or catheterisation and aneurysmal dilatation of the aorta were easily detected In sections examined

Fig 1

Fig 2

Fig 3

Fig 1 Normal curved appearance of aortic arch (A) C = Superior vena cava

Fig 2 Section through aortic arch in patient with aneurysmal dilatation of thoracic aorta

Fig 3 Left subclavian artery (arrow) bulges into apex of left lung

The left subclavian artery appeared as a mediastinal prominence bulging into th apex of the left lung (Fig 3) GOLDWIN et coll (1977) reported the left subclavia artery to be visible in 88 per cent of 68 patients In the present series the ascendin and descending aorta (Fig 4) were visible in the right anterior and the left posteric part of the mediastinum respectively An anomalous right aorta with the aort arch passing to the right of the trachea is illustrated in Fig 5

The main pulmonary artery appeared to the left of the ascending aorta (Fig 4 The right pulmonary artery (Fig 4) curved behind the ascending aorta and th superior vena cava in front of the main right bronchus Due to its longer horizont part the right pulmonary artery was easier to recognize than the left GOLDWI et coll reported the distance between the right main bronchus and the superior ve cava to be a fairly accurate estimate of the diameter of the right pulmonary arter and possibly useful in evaluating pulmonary arterial hypertension

Sections through the thoracolumbar junction clearly demonstrated the aor between the diaphragmatic crura prevertebrally more or less to the left of the mi

a b

Fig 9 Section through thoracolumbar junction a) Image with high window level Vertebra with two osteophytes (arrows) separated by a shallow groove with a smooth margin b) Same section with lower window level The groove between the osteophytes corresponds exactly to the aorta (A)

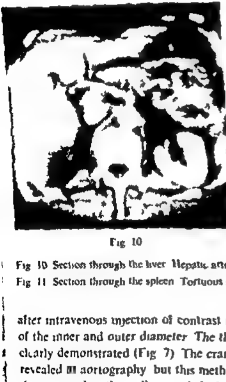


Fig 10

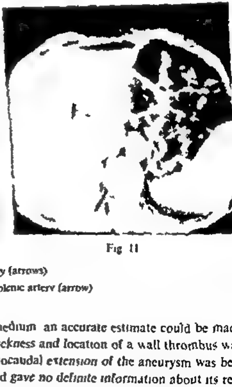


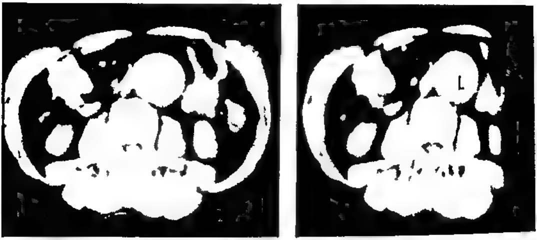
Fig 11

Fig 10 Section through the liver Hepatic artery (arrows)

Fig 11 Section through the spleen Tortuous splenic artery (arrow)

after intravenous injection of contrast medium an accurate estimate could be made of the inner and outer diameter The thickness and location of a wall thrombus was clearly demonstrated (Fig 7) The craniocaudal extension of the aneurysm was best revealed by aortography but this method gave no definite information about its real diameter unless the wall was calcified or adjacent structures displaced

In one patient a narrow structure no wider than the superior mesenteric artery



a b

Fig 7 Section through the lower pole of the kidneys in a patient with aneurysm of abdominal aorta a) Before b) after intravenous injection of contrast medium The size of the lumen (L) and the thickness of the wall are evident

a

b

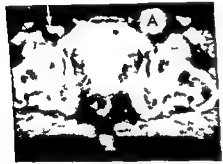
Fig 8 a) Section through the kidneys in a 13 year old girl with abdominal pain Aorta (→) narrow not wider than superior mesenteric artery (↔) b) Aortography confirms that aortic stenosis is present above and below the level of the renal arteries

Fig 16

Fig 17

Fig 16 Section through the left renal artery (arrow) The left renal vein crosses the midline in front of the aorta

Fig 17 Section through the inguinal regions Calcified femoral arteries (arrows) The femoral veins visible medial m the arteries



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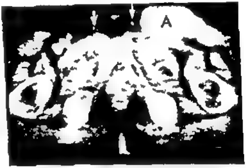


b

Fig 18 Sections through the inguinal regions Large left sided pseudoaneurysm arising from the femoral artery a) Upper part of the pseudoaneurysm (A) Right femoral artery (arrow) with the medially located vein the same structures on the left side are indistinguishable due to the pathologic condition b) More caudal section The pseudoaneurysm (A) simulates an inguinal mass The spermatic cords (arrows) run nearer the midline than the wider femoral arteries

(Culver & Pirson 1956) Shapiro & Batt (1960) described one case with a right descending aorta and osteophytes limited to the left side They suggested the unilateral absence of osteophytes to be due to aortic pulsations Goldberg & Carter (1978) demonstrated at computer tomography the absence of thoracic osteophytosis m the region adjacent to the aorta They came to the conclusion that aortic pulsation prevented osteophyte formation

The hepatic artery appears in Fig 10 but was not demonstrated in all patients The splenic artery was less frequently distinguished than the splenic vein because of its greater tortuosity The artery could be identified when its curves lay within the

Fig 12

Fig 13

Fig 12 Calcifications of the splenic artery (arrow) may simulate those of a chronic pancreatitis

Fig 13 Fatty liver and chronic pancreatitis with calcifications of the pancreas (arrow)

Fig 14

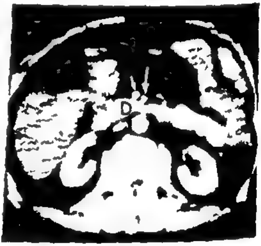


Fig 15

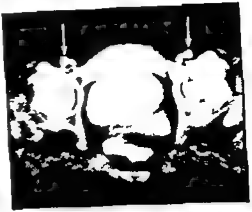
Fig 14 Superior mesenteric artery (arrow) surrounded by retropancreatic fat serves as a landmark to the pancreas (P) which curves in front of it across the midline

Fig 15 Section through the third horizontal part of duodenum (D) which crosses the midline behind the superior mesenteric artery (large arrow) and vein (small arrow)

was observed at the site of the aorta (Fig 8 a) Angiography (Fig 8 b) confirmed the presence of a stenosis at the level of the renal arteries and in addition stenoses of both subclavian arteries The combined radiologic and clinical findings indicated arteritis

In patients with degenerative lesions of the spine osteophytes could be observed on both sides of the aorta but not immediately adjacent to it (Fig 9) A predominance of right sided hypertrophic thoracic spurring is known from conventional films

Fig 16



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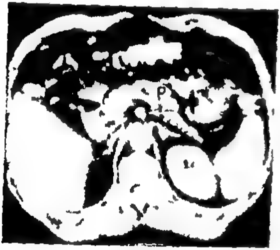
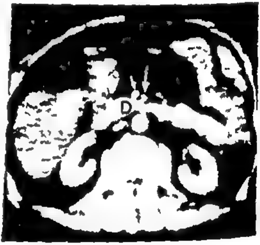


Fig 14



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RESUME

Des coupes transversalles montrant les structures artérielles normales et anormales ont été selectionnees sur un total de 1 810 examens tomodensitometriques du thorax et de l abdomen Les auteurs soulignent l importance radiologique de ces structures

REFERENCES

ULVER G J and PIRSON H S Asymmetry of osteophytosis in thoracic spine Amer J Roentgenol 76 (1956) 1157

OLDBERG R P and CARTER B L Absence of thoracic osteophytosis in the area adjacent to the aorta Computed tomography demonstration J Computer ass Tomogr 2 (1978) 173

OLDWIN R L HEITZMAN E R and PROTO A V Computed tomography of the mediastinum Radiology 124 (1977) 235

OLBENSTVEDT A KOLMANNSKOG F and AAKHUS T Venous structures of the chest and abdomen at computer tomography Acta radiol Diagnosis 20 (1979) 513

REEL L Computerized tomography using the EMI general purpose scanner Brit J Radiol 50 (1977) 2

HAPIRO R and BATT H D Unilateral thoracic spondylosis Amer J Roentgenol 83 (1960) 660

TANLEY R J SAGEL S S and LEVITT R G Computed tomographic evaluation of the pancreas Radiology 124 (1977) 715

plane of the section (Fig 11) If the splenic artery was calcified (Fig 12) the calcifications sometimes simulated those of the pancreas in chronic pancreatitis (Fig 13) If doubt existed as to the nature of the calcifications a conventional film was as a rule sufficient to differentiate between the two conditions

Of all the main branches of the aorta the superior mesenteric artery was the most easy to identify It was surrounded by the retropancreatic fat and the pancreas characteristically curved in front of it (Fig 14) along with the splenic vein This relationship was so constant that the artery could serve as a guide to the pancreas The horizontal third part of the duodenum also curved across the midline in front of the aorta in a fashion similar to that of the pancreas However in contrast to the pancreas the duodenum passed behind the superior mesenteric artery and vein (Fig 15) as also described by STANLEY et coll (1977) The duodenum the left renal vein and occasionally the uncinate process of the pancreas were the only identifiable structures between the aorta and the superior mesenteric artery

The renal arteries (Fig 16) were less frequently identified than the renal veins If the origin of the arteries was visible, this could contribute to a determination of the correct projection at nephroangiography in patients with suggested renal artery stenosis

The femoral arteries were identified in the inguinal regions (Figs 17 18) immediately lateral and slightly anterior to the veins The spermatic cords could simulate the femoral arteries but they were smaller and situated more medially (Fig 18) In one case (Fig 18) a pseudoaneurysm of the femoral artery appeared as a large inguinal mass which made identification of the femoral artery and vein impossible

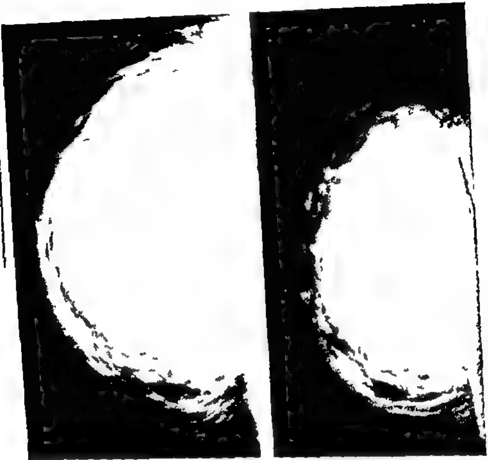
Comments The importance of non invasive methods such as computer tomography is rapidly increasing in clinical radiology Angiography remains the most exact method in the evaluation of vascular lesions, but much information is obtained at computer tomography Arterial aneurysms pseudoaneurysms and aortic stenosis can be identified Disappearance of the normal sharp outline of the aorta may indicate neoplastic infiltration of the periaortic fat The superior mesenteric artery serves as a useful guide to the pancreas and the horizontal third part of the duodenum A knowledge of the anatomy of transverse sections, including the vascular structures is necessary for the correct analysis of the images

SUMMARY

Cross sections illustrating normal and abnormal arterial structures were selected from a total of 1810 CT examinations of the chest and the abdomen The radiologic importance of these structures is pointed out

ZUSAMMENFASSUNG

Querschnitte die normale und pathologische arterielle Strukturen illustrieren wurden von insgesamt 1 810 CT Untersuchungen des Brustkorbes und des Abdomens ausgewählt Die rontgenologische Bedeutung dieser Strukturen wird hervorgehoben



a b

Fig 1 Case 1 a) Circumscribed tumor of high attenuation, separated from the normal parenchyma by a zone of less attenuation b) Penetrated film and a slightly altered projection The internal structure is inhomogeneous resembling normal parenchyma

Mammary radiography revealed an oval well circumscribed tumor of high attenuation (Fig 1 a) The tumor measured 11 cm 7 cm and occupied more than 50 per cent of the total volume of the breast It was separated from the normal parenchyma by a zone of less attenuation but no definite capsule was present The lesion appeared inhomogeneous with *a structure resembling normal mammary parenchyma (Fig 1 b) The rest of the parenchyma* was displaced towards the periphery and compressed Fine needle aspiration gave a few drops of cell free fluid and regular epithelial cells At operation the tumor was easily enucleated without bleeding The tumor was well circumscribed lens shaped (Fig. 2) with a diameter of 9 cm and weighing 140 g Microscopy revealed mammary tissue with ducts and lobules (Fig 3) and interlobular fibrosis with numerous capillary vessels partly also edema No recurrence was found one year postoperatively

Case 2 Age [redacted] One child Never treated with hormones At the age of 51 operated upon because of a small tumor in the left breast Microscopy revealed fibrous mammary tissue Now admitted because of pain in the left breast No tumor could be palpated

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MAMMARY HAMARTOMAS

I. ANDERSSON, J. HILDELL, F. LINELL and U. LJUNGQVIST

Circumscribed mammary lesions which are microscopically composed of normal or dysplastic mammary tissue have been reported under different names such as *isoliertes Brustdrusengewebe mit sekundaren Veranderungen* (PRYM 1928) fibroadenolipoma (SPALDING 1945) and postlactational breast tumor of a peculiar type (HOGEMAN & ÖSTBERG 1963, 1968). The term hamartoma was proposed by ARRIGONI et coll. (1971) and seems today to be the most widely accepted.

Only a few reports on this entity have appeared in the radiologic literature, most of them under the name of fibroadenolipoma. It has a characteristic radiographic appearance and may be considered as a form of hamartoma (DURSO 1971, DYREBORG & STARKLINT 1975). Recently 16 cases of mammary hamartoma were reported by HESSLER et coll. (1978). Some of these cases apparently had an appearance differing from that which has been described as typical fibroadenolipoma. As a contribution to the knowledge of the radiographic appearance of mammary hamartoma 5 cases are now described.

Case reports

Case 1. Age 42. No children. One abortion at the age of 38 and since then observed a lump in the left breast. Never treated with hormones. No pain and no secretion from the mamilla. The left breast was significantly larger than the right one and a large, rounded soft lump was found on palpation.

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Fig 4 Case 2 Large oval circumscribed tumor displacing and compressing the normal parenchyma

circumscribed round tumor measuring 8 cm 8 cm weighing 132 g was easily enucleated without bleeding Microscopically regular ducts and lobules were found in an abundant connective tissue with islets of fatty tissue No recurrence one year postoperatively

Case 3 Age 64 No children Eleven years earlier the left breast was operated upon because of a circumscribed tumor palpated on a screening examination A local excision was made including a part of the tumor Microscopy revealed marked fibrosis

At mammary radiography a circumscribed tumor measuring 12 cm 8 cm with varying attenuation and containing a few coarse calcifications was demonstrated (Fig 5) A hamartoma was suggested On palpation a rounded lens shaped tumor was found easily enucleated at operation Microscopy revealed a tumor composed of fibrotic almost hyaline tissue occasional regular ducts and lobules but without adipose tissue No recurrence one year postoperatively

Case 4 Age 26 One child 12 months old After ceasing a 6-month suckling period the patient had a condition resembling mastitis in the left breast Antibiotics had no effect After disappearance of the pain palpation revealed a lens-shaped tumor in the subareolar region of the breast The tumor had a diameter of 3 cm and appeared benign on clinical examination

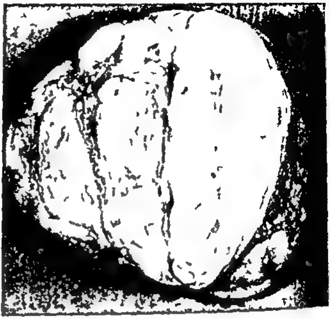

Fig 2 Case 1 Gross appearance of the excised tumor which is well circumscribed and lens shaped The cut surface in the middle is glistening and edematous

Fig 3 Case 1 Microphotograph Well delineated periphery to the right Dense fibrous stroma with ordinary lobules and some slightly dilated ducts In the middle downwards edema H&E ×40

Mammary radiography revealed an oval fairly well circumscribed tumor measuring 8 cm × 6 cm (Fig 4) The normal parenchyma was displaced and compressed by the tumor which was inhomogeneous with a structure resembling fibroadenosis Retrospectively it could be observed on a film obtained 3 years earlier Apparently it had not increased in size At fine needle aspiration no diagnostic material was obtained At operation a well

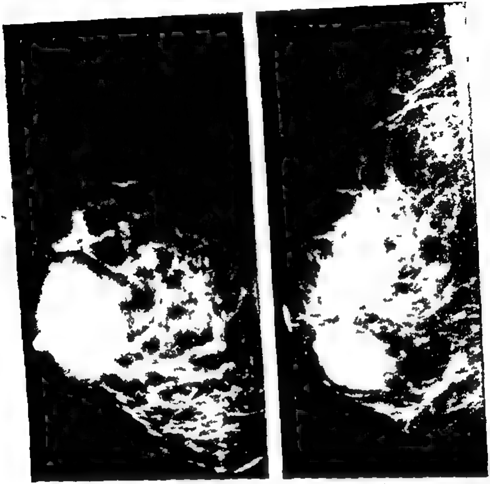

Fig 6 a) Case 4 b) Case 5 Well circumscribed oval tumor of high attenuation Zone of less attenuation and a structure resembling a caspsule around the tumor

Discussion

The described lesions have several characteristic features

(1) They were unilateral and some were very large (One of the lesions reported by HOGEMAN & ÖSTBERG (1968) weighed 1 400 g)

(2) Radiographically they were rounded or oval and well circumscribed Some tumors had a high and homogeneous attenuation others a varying attenuation Peripherally a zone of less attenuation was present delimited by a structure resembling a capsule

(3) They were easily enucleated at operation The radiographically observed zone of less attenuation probably represents the cleavage between the tumor and

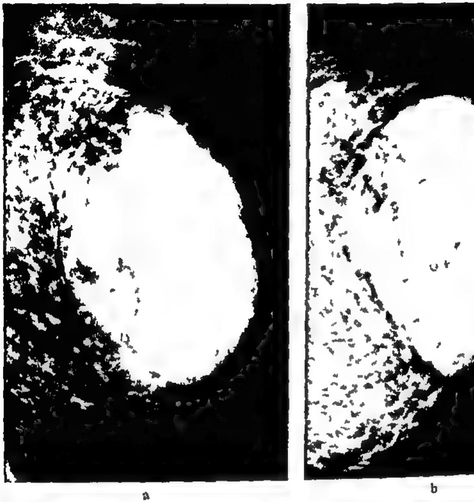

Fig. 5. Case 3. Large circumscribed tumor of relatively high attenuation containing a few coarse calcifications. a) Lateral. b) cranio-caudal projection.

Mammary radiography revealed an oval, well circumscribed tumor of high attenuation measuring 3 cm in diameter (Fig. 6 a). It was partly surrounded by a 2 mm wide well defined zone of less attenuation. Tissue consistent with fibroadenosis was obtained at fine needle biopsy. At operation the tumor was easily enucleated without bleeding. Microscopy revealed a well circumscribed tumor with normal ducts and lobules. No recurrence one year postoperatively.

Case 5. Age 52. Two children. Never treated with hormones. No symptoms from the breasts. A screening mammary radiography revealed an oval, well circumscribed tumor of high attenuation distal to the mamilla (Fig. 6 b). The tumor had a diameter of 3.5 cm and was partly surrounded by a 2 mm wide zone of less attenuation. This zone was demarcated from the surroundings by a thin structure resembling a capsule. Clinical examination revealed a lens shaped tumor with benign characteristics. At fine needle aspiration only a few regular epithelial cells and some macrophages were obtained. The tumor was easily excised. Microscopy revealed a well circumscribed tumor composed of hyaline connective tissue and regular ducts and lobules. No recurrence postoperatively.

more or less inhomogeneous although clearly different from fibroadenolipomas This was evident in the large hamartomas of Cases 1 to 3 and is probably of importance for differentiating hamartomas from large circumscribed tumors such as cystosarcoma phyllodes The form is usually oval Hamartomas of this type are usually surrounded by a zone of less attenuation which may be wider than is common with benign tumors such as cysts or fibroadenomas This zone may be delimited by a structure resembling a capsule which further differentiates hamartomas from other benign tumors

SUMMARY

Five cases of mammary hamartoma are described with special reference to the radiographic features Hamartomas are well circumscribed lesions composed of normal or dysplastic mammary tissue They are probably more common than has been anticipated from the literature and are important because they may be confused with other well circumscribed tumors such as cystosarcoma phyllodes The radiographic characteristics of hamartoma allows a tentative diagnosis in most cases

ZUSAMMENFASSUNG

Funf Patienten mit einem Hamartom der Mamma werden unter besonderer Berucksichtigung des rontgenologischen Aussehens beschrieben Hamartome sind gut abgegrenzte Veranderungen die aus normalem oder dysplastischem Brustgewebe bestehen Sie sind wahrscheinlich gewohnlicher als von der Literatur her angenommen werden kann und sind bedeutungsvoll da sie mit anderen gut abgegrenzten Tumoren wie Cystosarcoma phyllodes verwechselt werden konnen Die rontgenologischen Charakteristika der Hamartome erlauben eine Wahrscheinlichkeitsdiagnose in den meisten Fallen

RESUME

Les auteurs decrivent en particulier au point de vue radiographique cinq cas d hamartome mammaire Les hamartomes sont des lesions bien circonscrites composes de tissu mammaire normal ou dysplasique Ils sont probablement plus frequents qu il ne parait dans la litterature et sont importants car ils peuvent etre confondus avec d autres tumeurs bien circonscrites telles que les cystosarcomes phyllodes Les caractères radiographiques des hamartomes permettent dans la plupart des cas d essayer d en faire le diagnostic

REFERENCES

ARRIGONI M G DOCKERTY M B and JUDD E S The identification and treatment of mammary hamartoma Surg Gynec Obstet 133 (1971) 577

DURSO E A Mammographic findings in adenolipoma J Amer med Ass 218 (1971) 886

DYREBORG U and STARKLINT H Adenolipoma mammae Acta radiol Diagnosis 16 (1975) 362

the normal mammary tissue Hence if a capsule existed this was left behind After removal of the tumor a normal amount of mammary tissue remained

(4) Microscopically they were composed of normal or dysplastic mammary tissue with normal ducts and lobules Fibroadenosis was present in some cases The relative amount of glandular and adipose tissue varied Also microscopically the lesions were well delimited from the surrounding tissue although no capsule was evident

Although previously described by PRYM the first adequate clinical and pathologic description was given by HOGEMAN & ÖSTBERG (1968) They reported 3 cases which they called a postlactational breast tumor of a peculiar type The occurrence of the lesions after lactation may have been a coincidence Of the 5 present cases only one occurred after a lactational period and ARRIGONI et coll stated that the lesions might appear independent of pregnancy or lactation It is possible that these lesions are more easily recognized after lactation because the involution of the isolated islands of mammary tissue is slower than that of normal tissue

Recently HESSLER et coll reported 16 cases collected from a series of 10 000 patients with radiography of the breasts They pointed out that mammary hamartomas probably are more common than anticipated from the literature The present 5 cases were diagnosed between 1976 and 1978 in the city of Malmo which has about 240 000 inhabitants Two of the cases described by HOGEMAN & ÖSTBERG (1968) were diagnosed during 1962 and 1963 and belong to the same population There is a strong reason to believe that lesions of this type at least if small escape detection

The clinical findings were uncharacteristic in Cases 1 and 2 The lesions in Cases 3 4 and 5 were firm on palpation freely movable and lens shaped This shape is suggestive of hamartoma

The microscopic features were described by HOGEMAN & ÖSTBERG (1968) and will be described in further detail in a larger series (LINELL et coll 1979) It should only be emphasised in this connection that the lesions are microscopically clearly differentiated from fibroadenomas

According to HESSLER et coll the radiographic appearance of the lesions depends on the fat/parenchyma ratio The fat component was relatively slight in the present cases Probably a gradual transition may be found to lesions described as fibro adenolipoma (DURSO DYREBORG & STARKLINT MENGES & WURSTER 1976) The characteristics of fibroadenolipoma and the lesions in the present report are essentially the same the difference being that the stroma of fibroadenolipoma is composed mainly of fatty tissue

On the basis of previous reports and the present experiences it appears that two main types of hammartomas can be distinguished radiographically

(1) Fibroadenolipomas which have a characteristic mottled appearance due to the amount and distribution of fat A capsule is usually visible

(2) Hamartomas with a more homogeneous attenuation These lesions may be

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TANTALUM LABELLING IN VIVO OF CARDIAC VENTRICULAR CHAMBERS IN DOGS

M J LIPTON H G RINGERTZ R G HOLT and E CARLSSON

Cardioangiography provides an excellent demonstration of the anatomic structures of the heart for both clinical and experimental purposes However injection of a large amount of contrast medium may change the delicate functional balance and make the data obtained invalid The observation time is short approximately 3 or 4 cardiac cycles and repeated injections may produce unwanted and uncontrolled responses (BROWN et coll 1967 LEVINSON et coll 1966 DAVILA & SANMARCO 1966) It would be desirable therefore to have a method which provides similar information but which avoids the limitations imposed by catheterization and injection of contrast medium Such a technique has been developed and used (CARLSSON & MILNE 1967) This method involves the embedding of tantalum coils in the ventricular myocardium as permanent marker points These minute spirals can be implanted via a cardiac catheter The insertion does not require either thoracic or cardiac surgery and therefore has the advantage of a closed chest preparation (RINGERTZ et coll 1976) However the method has certain disadvantages a major one being the technical difficulty in placing the catheter so that it reaches all ventricular areas Sites near the aortic and pulmonary valvar roots are among the most difficult ones to reach with the catheter This method also has the disadvantage of requiring an arteriotomy and subsequent ligation of a peripheral artery If the right ventricle is also labelled a vein must be sacrificed at the end of the labelling procedure Therefore a modifica

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HESSLER CH, SCHNYDER P and OZZELLO L Hamartoma of the breast Diagnostic observation of 16 cases Radiology 126 (1978) 95

HOGEMAN K E and ÖSTBERG G Unilateral mammary hyperplasias Acta path microbiol scand 59 (1963) 560

— — Three cases of postlactational breast tumor of a peculiar type Acta path microbiol scand 73 (1968) 169

LINELL F ÖSTBERG G SÖDERSTRÖM J ANDERSSON I HILDELL J and LJUNGQVIST U Breast hamartomas An important entity of mammary pathology Virchows A h 383 (1979) 253

MENGES V und WURSTER K Fibro Adeno Lipom der Mamma Fortschr Rontgenstr 125 (1976) 192

PRYM P Pseudoadenome Adenome und Mastome der weiblichen Brustdruse Beitr path Anat 81 (1928) 1 221

SPALDING J E Adeno lipoma and lipoma of the breast Guy s Hosp Rep 94 (1945) 80

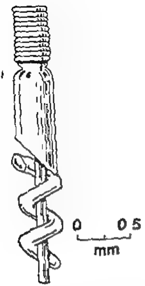

Fig 3 Screwdriver tip with tantalum screw

embedding of the coil in the wall of the material Catheters of different shapes are desirable since with a ventricular puncture manipulation is a little more restricted than in the case of regular catheterization through a peripheral vessel The inner diameter of these catheters was approximately 0 48 mm and enabled tantalum coils of 0 42 mm in diameter and approximately 2 mm in length to pass smoothly through their lumen The needle with a catheter placed snugly over it so that just the needle tip extended beyond the end of the catheter was positioned at a xiphisternal incision using biplane fluoroscopy

Eight mongrel dogs weighing between 13 and 16 kg were anesthetized using sodium pentobarbital in a dose of 0 5 ml per kg intubated and connected to a Harvard respirator for control of ventilation Each animal was placed on the fluoroscopic table on its right side which provided a lateral projection using a vertical radiation beam It is important to ensure that the projection is a true lateral if accurate screw placement in this plane is desired Continuous electrocardiographic monitoring was instituted A small incision was made with the tip of a scalpel blade just below the xiphoid process The tip of the needle system was then placed at this incision and positioned so that the long axis of the needle was in line with the long axis of the cardiac silhouette seen fluoroscopically The needle was then advanced until it reached the cardiac apex and was then briskly introduced into the ventricular mass and quickly removed leaving the catheter within the heart A jet of blood confirmed the intraventricular position of the catheter A monitoring pressure line was used to control the cavity pressure The size and shape of the ventricular chamber and the relative position of the catheter within it were then demonstrated by a small contrast medium injection A stopcock was attached to the catheter to control bleeding The

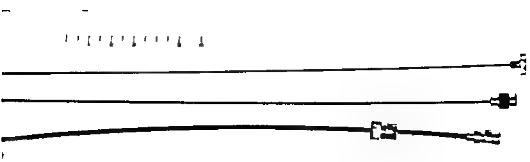

Fig 1 Needle system

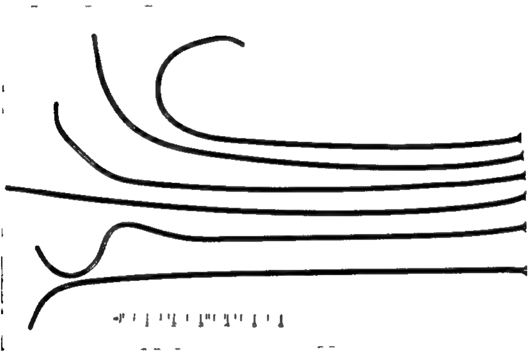

Fig 2 A series of preshaped catheters

tion of this approach is now proposed It requires a much shorter catheter and is performed by direct chest wall puncture The objectives were to develop an alternative and simple technique for labelling the endocardium and make easier the labelling near the valves while maintaining a closed chest preparation

Methods and Materials

A needle system approximately 28 cm long was built (Fig 1) consisting of a 0 45 mm (18 gauge) translumbar needle over which a variety of short preshaped catheters could be placed (Fig 2) The catheter material must be reasonably strong in order to permit the passage of the screw through its lumen without distortion kinking or

during the passage of the needle system through the ventricular apex and subsequently with catheter manipulation and screw implantation This did not significantly impede the screw implantation exercise

Results

Complications during the labelling procedure included pericardial hemorrhage arrhythmia pneumothorax and hemothorax, particularly when numerous needle passes were required These problems arose during the initial experiments while the technique was being worked out However 6 of the 8 dogs survived the procedure and one week later appeared to have made a complete recovery with no ECG abnormalities at that time Chest films were normal Left ventricular contraction as estimated from cardiac output and aortic and ventricular pressures were normal in 4 of 5 dogs One dog had a moderate degree of aortic regurgitation which was related to injury of the aortic valvar leaflet during the coil placement procedure No complications occurred in the 4 last experiments A left ventricular chamber labelled with tantalum coils is illustrated in Fig 4 A frame from a contrast medium injection into the left ventricle via the catheter placed directly through the chest wall into the ventricle appears in Fig 5 The right ventricle can also be labelled but it is easier technically to instrument the left ventricle although with practice the right can be selectively punctured

Discussion

This technique provides a new method of preparing a canine model for the investigation of segmental or total ventricular function It has the advantage of a closed chest preparation and leaves all the peripheral vessels intact for later instrumentation which may be important for chronic experimentation This model has been used for cineradiography of conscious animals and moment to moment changes in ventricular function (LIPTON et coll 1978) Screw motion analysis is free from the many disadvantages of conventional cardioangiography in particular the problem of repeated and accurate observations at short intervals is solved

Acknowledgement

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The work was performed while one of the authors (M J L) was on sabattical leave from Stanford University serving as a Research Associate Department of Radiology and Visiting Scientist Cardiovascular Research Institute University of California San Francisco California

SUMMARY

Demarcating fixed points in cardiac ventricles in the dog by catheter placement of tantalum coils has been shown to provide an excellent physiologic model A new method employing

Fig 4

Fig 5

Fig 4 Left ventricle labelled with tantalum coils Lateral projection

Fig 5 Injection of contrast medium into left ventricle performed via transthoracic catheterization Lateral projection

most important part of the instrument used for introduction of the screws was the drive shaft made from a flexible guidewire modified at the tip in such a way that a receptacle and driving shoulder was formed (Fig 3) Over the receptacle end a spiral of tantalum wire, 1 mm long and 0 42 mm wide was threaded and the whole assembly introduced through the catheter into the cardiac chamber to be labelled The catheter tip was gently pressed towards the endocardial surface When contact was made the drive shaft was rotated thereby screwing the tantalum wire into the myocardium When fixed in the myocardium the drive shaft was gently withdrawn leaving the screw embedded in the myocardium The catheter tip was given a rounded blunt shape in order to prevent the tantalum wire from becoming too deeply embedded A series of screws can be rapidly implanted in almost any desired position with this technique The catheter can be manipulated in such a way that each major area of the cavity wall can be reached This was usually possible with one catheter but the series of catheter shapes illustrated in Fig 2 was available and any one of these catheters could be exchanged over the guidewire system when required A small test injection of contrast medium before and after the screw placement was of great help in confirming that the coils were placed close to the edge of the chamber at the desired points in the lateral plane Ectopic beats occurred frequently both

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DETERMINATION OF BLOOD FLOW THROUGH ARTERIOVENOUS FISTULAE AND SHUNTS

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Over the past decade hemodialysis has been the generally accepted method for treatment of acute and chronic renal failure (Bell & Calman 1974) Renal transplantation and regular dialysis therapy are now normal routines in many medical centers Since the development of a clinically useful artificial kidney creation of a long term access to the circulation has been the major issue for successful application of hemodialysis in the individual case (Bailey & Morgan 1972) From the first attempt to create a long term circulatory access by an arteriovenous shunt of glass (Allwall et coll 1948) further development of materials and techniques has led to clinically useful external arteriovenous shunts and subcutaneous arteriovenous fistulae At the present time the subcutaneous arteriovenous fistula seems to be the access of choice compared to the previous and still important Teflon Silastic shunt The internal arteriovenous fistula has a number of advantages regarding clotting sepsis and longevity Successful dialysis over several years has been reported with fistulae patients also prefer the subcutaneous location

However with both techniques creation of an artificial arteriovenous communication may severely influence the cardiovascular hemodynamics as well as reduce blood flow distal to the shunt/fistula Thus it is documented that such arteriovenous communications increase the cardiac output (Harrison et coll 1924 Cohen et coll 1948 Nickerson et coll 1951) pulmonary arterial pressure heart rate and also

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direct ventricular puncture has been developed for implanting these markers The method has several advantages over an earlier peripheral catheter technique Apical approach allows easier screw placement near the aortic and pulmonary valves Peripheral vessels are left intact and pressure monitoring as well as contrast medium injection can be performed through the same catheter

ZUSAMMENFASSUNG

Die Markierung von fixierten Punkten im Herzventrikel des Hundes durch Katheterplazierung von Tantalum Ringen erwies sich als ausgezeichnetes physiologisches M d ll Eine neue Methode mit direkter Ventrikelpunktion wurde entwickelt um diese Markierungen zu implantieren Die Methode hat verschiedene Vorteile gegenuber der fruhern peripheren Kathetertechnik Eine Einfuhrung durch die Herzspitze erlaubt es eine ber Schrauben nahe der Aorta und den Pulmonalisklappen anzubringen Die peripheren Gefasse werden intakt gelassen und Druckmessungen sowie Injektion von Kontrastmittel konnen durch denselben Katheter vorgenommen werden

RESUME

L expérimentation a montré que le repérage de points bien déterminés dans les ventricules cardiaques du chien grace a la mise en place par un cathéter de ressorts de tantale donne un excellent modele physiologique Les auteurs ont mis au point une nouvell mé thode utilisant la ponction directe du ventricule pour implanter ces marqueurs Cette mé thode a plusieurs avantages sur la technique de cathétérisme périphérique utilisée aupara ant La voie apicale permet de visser plus facilement les marqueurs du voisinage des va e aortiques et pulmonaires Les vaisseaux périphériques restent intacts et la surveillance de la pression ainsi que l injection de moyen de contraste peut etre faite par le meme catheter

REFERENCES

BROWN T G JR HOPPE J O and BORISENOK W A Cardiovascular studies of Isopaque B and other radiopaque media Acta radiol (1967) Suppl No 270 p 58

CARLSSON E and MILNE N C Permanent implantation of endocardial tantalum screws A new technique for functional studies of the heart in the experimental animal J Canad Ass Radiol 19 (1967) 304

DAVILA J C and SANMARCO M E An analysis of the fit of mathematical models applicable to the measurement of left ventricular volume *In* Symposium on measurement of left ventricular volume Part I Amer J Cardiol 18 (1966) 31

LEVINSON G E NADIMI M CONRAD W A and HELMI K I The effect of angio ardio graphic dye on left ventricular volumes J clin Invest 45 (1966) 1039

LIPTON M J RINGERTZ H G and CARLSSON E The validity of quantitative regiona myocardial motion studies To be published in Circulation

RINGERTZ H G TYBERG J V and CARLSSON E A method for the study of regional ischemic dysfunction in the intact dog Permanent endocardial markers and the pressure length loop Invest Radiol 11 (1976) 556

Fig 1 Angiography of patient with bovine arteriovenous fistula between the right femoral artery and vein a) Rapid filling of the fistula b) Contrast accumulation in the iliac vein 2 seconds later

(Fig 1) The patient (age 20) had chronic renal disease after failure of a kidney transplant Several access procedures were required to enable hemodialysis including a bovine arteriovenous fistula between the subclavian artery and vein The patient developed congestive heart failure Cardiac catheterization indicated that approximately 10 per cent of the cardiac output passed through the fistula Even though the fistula was not felt to be hemodynamically significant the subclavian fistula was closed and the present bovine arteriovenous fistula between the femoral artery and vein was created The surgical procedure was well tolerated but the congestive heart failure remained Angiography was performed to estimate the patency of the fistula At that time the VD recording was performed (Fig 2) By percutaneous technique a catheter was placed with the tip in the abdominal aorta just above the bifurcation Twenty ml of Renografin 60 was injected and the dilution of the injected medium was recorded on videotape during constant fluoroscopy over the right common femoral artery Ten min later a second injection was made (5 ml) through the same catheter

decrease the total peripheral resistance and systolic blood pressure (GUYTON & SAGAWA 1961, NAKANO 1971) These changes might contribute to congestive he failure (HOLMAN 1965) In patients with chronic renal failure such hemodynam changes are usually accentuated (BELL & CALMAN)

The local effects of an arteriovenous communication in the forearm or leg result in increased flow to that limb (HURWICH 1969, HERRON & WALLACE 1971). I has also been shown that when forearm fistula flow increases the blood flow to th hand (WAKIM & JANES 1958) and thumb (BUSSELL et coll 1971) decreases signif cantly compared to the contralateral hand

The assessment of blood flow through a shunt/fistula is of great clinical importanc For arteriovenous fistula, only indirect methods of uncertain clinical significance ar available In the present report a new method will be presented using videodensi metric (VD) technique The method can be applied in connection with routi angiography and is simple and accurate The estimate gives shunt flow as a fractio of the cardiac output

Relative flow estimated by videodensitometry

A videodensitometer is an electronic instrument capable of recording densi changes in any area of a TV image Applied to angiography videodensitometry can be defined as a technique for obtaining objective quantitative recordings of the temporal sequence of the dilution of a contrast medium in the circulatory system Thus it is a circulatory indicator dilution technique (WOOD et coll 1964) Compared to conventional dilution techniques the VD system has a rapid dynamic response which makes it possible to analyze events within a single cardiac cycle No sampl & catheters are needed and only one injection of contrast medium is required to obtain dilution curves from any vessel in the roentgen video image The concept of relativ flow measured by videodensitometry has been described by LANTZ (1974 1975) and has proven to be highly accurate in hydrodynamic models and animal experiments (LINK et coll 1979 LANTZ et coll 1980) By injecting contrast medium at two sites in a circulatory system and recording the dilution of the contrast at one locatio distal to both injection sites it is possible to compare the flows at the sites of in jection The recordings utilize fluoroscopy with fixed kV and mA The image i stored on videotape cassette and can be replayed multiple times to obtain dilutio curves after the angiography is completed By placing a VD cursor of optional siz over the artery displayed on the monitor VD dilution curves are obtained Th integrated areas of the dilution curves are inversely proportional to the flow at th sites of injection (LANTZ 1974)

Material and Methods

The present investigation was initiated by a VD flow estimate in a patient with bovine arteriovenous fistula placed between the femoral artery and the femoral vei

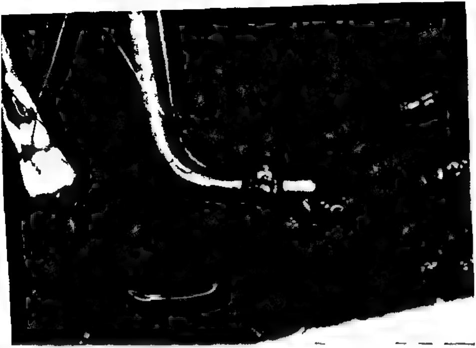

Fig 4 Detail of canine model with carotid graft placed between femoral artery and vein To the left electromagnetic cuff probe on distal external iliac artery

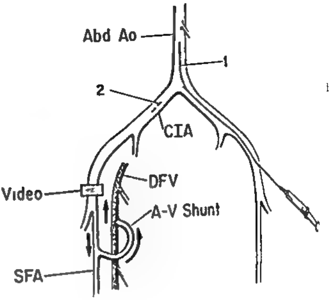

Fig 2 Diagram of patient with right arteriovenous fistula Recording is performed over the right femoral artery (video) after contrast injections at site 1 and 2 through a catheter from the right groin SFA = superficial femoral artery DFV = deep femoral vein CIA = common iliac artery Abd Ao = abdominal aorta

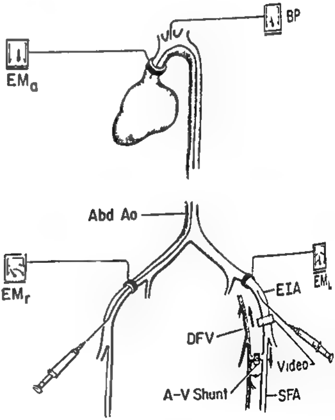

Fig 3 Canine model EM_a, EM_r and EM_l represent the sites for continuous electromagnetic recording of flow in aortic arch right and left external iliac arteries (EIA) SFA = superficial femoral artery DFV = deep femoral vein Recordings are obtained over the left femoral artery (video) after contrast injections in the aortic arch and the left external iliac artery

now with the tip in the proximal portion of the right common iliac artery The fluoroscopic recording site was the same

In order to reproduce the patient s condition and to analyse the acute hemodynamic parameters involved an in vivo canine model was designed (Fig 3) Two

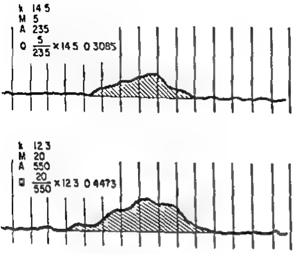

Fig 5 Videodensitometric flow calculation in patient Top curve represents the recording over right femoral artery after contrast injection in right common iliac artery Bottom curve represents the recording at the same site after contrast injection in distal abdominal aorta The flow Q is calculated from M (amount of contrast medium injected) A (integrated densitometric area shaded) and k (calibration factor for radiation intensity) according to Q = (M/A) k The flow in the right iliac artery as a fraction of distal aortic flow = 69 0 per cent

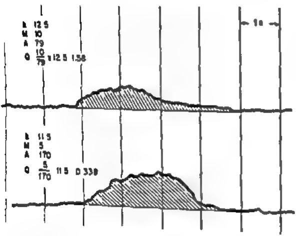

Fig 6 Calculation of flow in dog 2 Top curve represents videodensitometric recording over left femoral artery after contrast injection in aortic arch Bottom curve represents the recording at the same site after contrast injection in left external iliac artery (shunt open) Flow in left external iliac artery as a fraction of cardiac output is 21 4 per cent Same symbols as in Fig 5

dogs weighing 26 7 kg (1) and 21 7 kg (2) respectively were anesthetized with 30 mg/kg of sodium pentobarbitol and were ventilated with a Harvard ventilator on room air In dog 1 an arteriovenous fistula was created between the left femoral artery and vein by a graft taken from the right carotid artery The internal diameter of the graft was 3 mm equal to the size of the femoral artery (Fig 4) In dog 2 a larger arteriovenous communication was created at the same site utilizing plastic tubing with 6 mm internal diameter The cardiac output was continuously recorded by a circumferential electromagnetic (EM) flow probe around the ascending aorta 2 to 4 cm above the aortic valve The probe was connected to an EM flowmeter (Statham SP 2200) Similar EM flow probes simultaneously recorded the flow in both external

Table 2

Flow data in two dogs estimated by electromagnetic method Each figure represents an average of 6 to 12 readings

Line	Data	Dog 1	Dog 2
1	Weight (kg)	26 7	21 7
2	Shunt diameter (mm)	3	6
3	Cardiac output (ml min)	1 365	2 410
4	Ext il c artery (shunt side) (ml min)	196	473
5	Shunt (ml min)	145	437
6	Limb (shunt) (ml/min)	51	36
7	Limb (control) (ml/min)	70	55
	Per cent of cardiac output		
8	Ext iliac artery (shunt)	14 3	19 6
9	Shunt	10 6	18 1
10	Limb (shunt)	3 7	1 5
11	Limb (control)	5 1	2.3
12	Per cent of distal aortic flow to shunt side	73 6	89 5
13	Per cent reduction of flow to distal limb on shunt side	27 2	34 6

electromagnetic method The figures correlate extremely well with a difference in relative measure less than 2 per cent An example of one calculation is illustrated in Fig 6

Acute hemodynamic effects of shunt in two dogs The data are listed in Table 2 The blood pressure did not change significantly in either dog after repeated clamping of the shunt The cardiac output was considerably higher in dog 2 during the entire experiment The cardiac output increased significantly in this dog when the shunt was opened (2 410 ml/min and 2 133 ml/min respectively two tailed t statistics < 0 02) No difference in cardiac output could be seen in dog 1 which had a smaller shunt and a lower cardiac output

The iliac artery on the side of the shunt received about two times more flow in dog 2 with the larger shunt compared to dog 1 (Table 2 line 4) This higher flow contributed to an increase of the shunt flow and not to perfusion of the lower limb The limb perfusion on the side of the shunt was about 30 per cent less than the perfusion of the contralateral limb (Table 2 line 13)

Discussion

The videodensitometric method for estimating relative flow shows an excellent correlation with electromagnetic flow estimates This is in accordance with results of

Table 1

Relative flow estimates by electromagnetic method and videodensitometric method in dog 2

Shunt	Flow on shunt side	EM method (per cent)	Video method (per cent)
Open	Iliac artery flow / Cardiac output	21 5	20 3
		21 1	21 4
		19 9	21 4
Closed	Iliac artery flow / Cardiac output	1 4	1 9
		1 5	2 0
		1 6	2 3
		1 4	2 1
Closed / open	Iliac artery flow / Iliac artery flow	6 7	8 7
		6 8	8 5
		7 2	9 5

iliac arteries By percutaneous technique from the right groin a pigtail catheter w side holes was placed in the ascending aorta with the tip 2 cm above the aortic valve Another catheter with end and side holes was introduced into the left femoral arter with the tip in the left external iliac artery During injection of 10 ml Vascoray in the aortic arch the dilution curves were recorded in constant fluoroscopy with the image intensifier focused over the left femoral artery Following the aortic a injections similar recordings were obtained after 1 ml and 5 ml injections of Vascoray in the left external iliac artery Repeated injections were performed after clamp the arteriovenous fistula The equipment consisted of a constant potential generato (C G R 1215) connected to a Coronarix C arm (C G R) using a 10 cm (4) imag intensifier input Before each recording a 10 mm aluminum filter was used for ca bra tion of the radiation intensity

The data from the EM probes along with the systemic blood pressure from th left main carotid artery (Statham P23DB) was recorded on an Electronics for Medicin DR 8 photographic recorder and synchronized with the video recording of th contrast passage during fluoroscopy The flow estimates were made after the re cordings by replaying the cassette Integration of the VD mass time curves was pe formed by planimetry

Results

Flow estimates by video technique Calculation of the distribution of the dist aortic flow to the shunted iliac artery in the patient was 69 0 per cent (Fig 5) Th corresponded to 73 [illegible] per cent in dog 1 which had a shunt with a diameter equal that of the supporting artery

The VD estimate of flows is illustrated in Table 1 for dog 2 and compared to t

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SUMMARY

A videodensitometric method for estimating relative flow was employed in a patient with bovine arteriovenous fistula Analogous arteriovenous communications of different sizes ere created in two dogs for comparison Local and general hemodynamic parameters were easured The videodensitometric method proved to be highly accurate compared to electro agnetic flow readings and is the method of choice in estimating shunt flow in connection ith routine angiography

ZUSAMMENFASSUNG

Eine videodensitometrische Methode wurde zur Bestimmung der relativen Durchblutung bei einem Patienten mit einer bovinen arteriovenosen Fistel verwendet Analoge arteriovenose Verbindungen von verschiedener Grosse wurden bei zwei Hunden zum Vergleich hergestellt und lokale und allgemeine hamodynamische Parameter wurden gemessen Die videodensitometrische Methode erwies sich gut mit den elektromagnetischen Stromungsmessungen ubereinzustimmen und ist die Methode der Wahl zur Bestimmung der Shunt Durchblutung in Verbindung mit der Routine Angiographie

RESUME

Les auteurs ont utilisé une méthode vidéodensitométrique pour estimer le debit relatif chez un malade qui avait une fistule artério-veineuse par pontage bovin Ils ont crée des communications artério-veineuses semblables de différentes tailles sur deux chiens pour comparaison Ils ont mesuré les paramètres hemodynamiques locaux et géneraux La méthode vidéodensitométrique s est révélée très precise par comparaison avec les lectures electromagnetiques de débit et est la méthode de choix pour estimer le débit des shunts au cours de l angiographie de routine

REFERENCES

ALFREY A C LUEKER R GOSS J E VOGEL J H K FARIS T D and HOLMES J H Control of arteriovenous shunt flow J Amer med Ass 214 (1970) 884

ALLWALL N NORVITT L and STEINS A M An artificial kidney Clinical experiences of dialytic treatment of uremia Acta med scand 132 (1948) 587

BAILEY G L and MORGAN A P Circulatory access for hemodialysis *In* Hemodialysis Principles and practice p 211 Edited by G L Bailey Academic Press New York and London 1972

BELL P R F and CALMAN K C Surgical aspects of haemodialysis Churchill Livingstone Edinburgh and London 1974

renal flow (LINK et coll) and mesenteric and cerebral flow measurements (LA
et coll) The method is easy to apply in conjunction with routine angiography I
can be used in any area where a selective catheter can be placed The flow can th
be given as a relative measure compared to any other area Ideally, a selective cathe
should be placed with the tip in the shunt for contrast injection If another inject
is made in the aortic arch a direct measure of the shunt flow as a fraction of th
cardiac output can be calculated However, some possible errors have to be take
into consideration regarding the VD recordings First the electronic VD wi d
must be placed over a cross section of an artery so as to avoid other vessels contain
contrast medium If recirculating veins overlie the window, the window can be
repositioned and the tape replayed Secondly, the injection rate of contrast medium
should not exceed 1/4 of the flow rate at the site of injection Thirdly a small am
of medium washed out of the catheter tip This may represent a significant fraction
of a small contrast medium injection leading to an error in measurement of co
volume and thus causing error in measurement of relative flow Finally, calibrat
of the radiation intensity is advisable before each fluoroscopic recording It is
made by placing aluminum over the roentgen tube for a few seconds before ea
recording

Several other methods for measurement of flow through shunts and fistulae hav
been reported The flow through an external arteriovenous shunt can be estimate
by an electromagnetic flowmeter placed over the arterial outflow tubing after suitab
calibration (ALFREY et coll 1970) or placed in the circuit (BRENNAND & BURKE
1960) The flow through an arteriovenous fistula is more difficult to estimate Th
ultrasonic method using the Doppler principle can give an approximate value
the cross sectional area of the blood vessel can be obtained Plethysmography
the arm or the leg (HURWICH HERRON & WALLACE) might give a rough overa
indication of the flow to the limb but does not give a direct measure of the shu
flow The cardiac output measured before and after occlusion of the shunt will al
give an indication of flow This investigation suggests videodensitometry to be t
method of choice for accurate estimate of blood flow through shunts and fistulae
connection with routine angiography

The dog experiments confirmed that the shunt flow depends on the size of the shun
The flow to the lower limb on the side of the shunt was consistenly lower than
the control side (about 30 %) In dog 1 the shunt received 10 6 per cent of the cardi
output corresponding to a distribution of 73 6 per cent of the distal aortic flow to t
side of the shunt This corresponds well with the patient s situation (69 0 %) whe
it was estimated that the fistula did not shunt more than 10 per cent of the cardi
output The patient s congestive heart failure might be explained by metabolic facto
and chronic fluid overload due to renal failure In dog 1 no decrease of cardiac ou
put was noted by clamping the shunt In dog 2 however where the shunt receiv
18 1 per cent of the cardiac output a significant response was obtained by clampi
the shunt

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PORTAL PRESSURE CORRELATED TO VISCERAL CIRCULATION TIMES

L. FRIMAN

Life threatening hemorrhage may be a serious consequence of the circulatory alterations occurring in portal hypertension Liver cirrhosis is the most frequent cause of portal hypertension The most important circulatory change which occurs in liver cirrhosis appears to be obstruction of the venous flow BOOKSTEIN et coll (1975) used magnification hepatic wedge phlebography in cirrhotic patients and found more severe obstructive changes in the hepatic than in the portal veins giving rise to impaired *portal flow*

HALES et coll (1959) demonstrated *arterioportal shunts* in corrosion casts JOHNSON et coll (1966) found increased cardiac output blood volume and systolic ejection rate and a decrease in peripheral resistance in patients with liver cirrhosis They regarded these findings to be *similar to the findings* in patients with systemic arteriovenous *fistulae* VIAMONTE et coll (1968) demonstrated shunts between portal and hepatic veins and anastomoses between *hepatic veins* Consequently obstructive changes exist in liver cirrhosis to some degree they can be overcome by shunts in the liver but the dominant hemodynamic feature in cirrhosis is outflow obstruction rather than arteriovenous fistulae (WARREN et coll 1968) The great variability in vascularity and hemodynamics was emphasized by WARREN et coll (1967) who stated that high pressure does not necessarily occur in advanced cirrhosis but may appear in the early stage of disease

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BRENNAND B and BUNKER N V Electronic monitoring apparatus for the coil kidney Lancet I (1960) 578

BUSSELL J A ABBOTT J A and LIM R C A radial steal syndrome with arteriovenous *fistula for haemodialysis* Studies in seven patients Ann intern Med 75 (1971) 387

COHEN S M EDHOLM O G HOWARTH S, MCMICHAEL J and SHARPEY SCHAFER E P Cardiac output and peripheral blood flow in arterio venous aneurysm Clin Sci 7 (1948) 35

GUYTON A C and SAGAWA K Compensations of cardiac output and other circulatory functions in areflex dogs with large arteriovenous fistulas Amer J Physiol 200 (1961) 1157

HARRISON T R DOCK W and HOLMAN E Experimental studies in arteriovenous fistula cardiac output Heart 11 (1924) 337

HERRON A and WALLACE W F M *Blood flow through surgically produced* arterio venous fistulae in the human forearm Clin Sci 41 (1971) 7

HOLMAN E Abnormal arteriovenous communications Great variability of effects with particular reference to delayed development of cardiac failure Circulation 32 (1965) 1001

HURWICH B J *Plethysmographic forearm blood flow studies in maintenance haemodialysis* patients with radial arteriovenous fistulae Nephron 6 (1969) 673

LANTZ B M T A methodologic investigation of roentgen videodensitometric measurement of relative flow University of California Press Davis 1974

— Relative flow measured by roentgen videodensitometry in hydrodynamic model Acta radiol Diagnosis 16 (1975) 503

— FOERSTER J M HOLCROFT J W and LINK D P (a) Determination of cerebral flow by videodensitometry To be published in Acta radiol Diagnosis (1980)

— LINK D P FOERSTER J M and HOLCROFT J W (b) Determination of splanchnic flow by videodensitometry To be published in Acta radiol Diagnosis (1980)

LINK D P LANTZ B M T FOERSTER J M HOLCROFT J W and REID M H New videodensitometric method for measuring renal artery blood flow at routine arteriography Validation in the canine model To be published in Invest Radiol

NAKANO J Effect of arteriovenous fistula on the cardiovascular dynamics Jap Heart J 12 (1971) 392

NICKERSON J L ELKIN D C and WARREN J V The effect of temporary occlusion of arteriovenous fistulas on heart rate stroke volume and cardiac output J clin Invest. 30 (1951) 215

WAKIM K G and JANES J M Influence of arteriovenous fistula on the distal circulation *in the involved extremity* Arch phys med Rehabil 39 (1958) 431

WOOD E H STURM R E and SANDERS J J Data processing in cardiovascular physiology with particular reference to roentgen videodensitometry Mayo Clin Proc 39 (1964) 849

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HURWICH B J Plethysmographic forearm blood flow studies in maintenance haemodialysis patients with radial arteriovenous fistulae Nephron 6 (1969) 673

LANTZ B M T A methodologic investigation of roentgen videodensitometric measurement of relative flow University of California Press Davis 1974

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— FOERSTER J M HOLCROFT J W and LINK D P (a) Determination of cerebral flow by videodensitometry To be published in Acta radiol Diagnosis (1980)

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NAKANO J Effect of arteriovenous fistula on the cardiovascular dynamics Jap Heart J 1[illegible] (1971) 392

NICKERSON J L ELKIN D C and WARREN J V The effect of temporary occlusion of arteriovenous fistulas on heart rate stroke volume and cardiac output J clin Invest 30 (1951) 215

WAKIM K G and JANES J M Influence of arteriovenous fistula on the distal circulation in the involved extremity Arch phys med Rehabil 39 (1958) 431

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a phenomenon called arterial autoregulation. On the other hand, they recorded no alteration in portal flow after a decrease in hepatic arterial flow. Vasopressin infusion in the celiac artery in the dog has a biphasic effect on the hepatic arterial flow (BARR et coll. 1975). They registered an initial transient decrease in flow, followed by a substantial increase in spite of continued infusion. This increase was probably due to vasodilatation of the hepatic arteries in response to decreased portal flow which activated the autoregulatory mechanism in the liver, resulting in increased hepatic arterial flow. A direct correlation between the diameters of the hepatic arteries and the severity of the cirrhosis was demonstrated by REUTER et coll. (1975).

Splenomegaly is often regarded as a natural consequence of portal venous stasis. However, no significant correlation between the severity of cirrhosis and degree of splenomegaly was found by KROOK (1956) or by REUTER et coll. The reason for that is not known but may be related to the effectiveness of portosystemic collateral veins in modifying portal pressure (REUTER et coll.). An interesting observation made by the same authors was that the splenic area generally decreased after performance of a portocaval shunt. However, the size of both the splenic artery and the vein increased slightly. This apparently contradictory phenomenon might be explained by the increased visceral blood flow that occurs following a portocaval shunt because of the marked decrease in splenic vein pressure.

ABEATICI & CAMPI (1951) described splenic portography as a method for demonstrating the portal circulation. This method has some limits because no contrast filling of the portal vein may be obtained in some patients with portal hypertension although no occlusion of the portal vein exists (BERGSTRAND 1971). Another disadvantage of splenic portography is that it cannot be performed in splenectomized patients. Therefore BOIJSEN et coll. (1963) suggested angiography of the celiac and the superior mesenteric arteries as a method for demonstrating the portal vein, especially in splenectomized patients. NEBESAR & POLLARD (1966) regarded arterial injection to be a more physiologic method of demonstrating the portal circulation. They found angiography of the superior mesenteric artery to be the best method for obtaining filling of the portal vein, which was achieved in every case. The effect of bradykinin differs in the celiac and superior mesenteric circulation (BOIJSEN & REDMAN 1966). They suggested that the resistance to flow in the spleen and the liver is lower than in the superior mesenteric area because of anatomic differences in the vascularity. Morphologic abnormalities such as portosystemic collaterals have often been described in portal hypertension but alterations in circulation times appear to be less often analysed. BERGSTRAND & EKMAN (1957) using splenic portography demonstrated a reduced flow velocity in patients with portal hypertension but no correlation between the flow rate and the portal pressure. BOIJSEN et coll. noticed a slow passage of contrast medium from arteries to veins in patients with portal hypertension.

During 1974 to 1975 the circulation times in different visceral parts were compared

with the portal pressure in order to find out whether any correlation exists between the portal pressure and various circulation times and if so to ascertain whether it would assist in reaching a diagnosis of portal hypertension

Material

The material consisted of 17 patients 4 men and 13 women aged between 18 and 70 years and with a mean age of 54 The final diagnoses were based upon clinical examinations laboratory tests surgery and autopsy

Ten patients had portal hypertension and this group consisted of 9 patients with liver cirrhosis and one with thrombosis of the liver veins Seven patients had normal portal pressure 3 of these with malignancy one hypernephroma one carcinoma of the pancreas and one carcinoid tumour One patient had a chronic pericholangitis and unspecific hepatitis one a duodenitis—pancreatitis one an aneurysm of the splenic artery and finally in one patient no abnormality was found

Methods

Portal vein pressure was measured as wedge hepatic venous pressure in 14 patients The measurements were performed just before the angiography The pressure was determined according to KROOK The projected level of the right atrium 5 cm below the sternal angle with the patient in supine position was taken as the baseline In the remaining 3 patients the portal pressure was measured at operation within a few weeks after the angiography In 2 of them a spleno renal shunt was performed and the third had a liver vein thrombosis

Selective angiography of celiac and superior mesenteric arteries was performed after puncture of the femoral artery in the groin celiac angiography in all 17 patients and superior mesenteric angiography in 15 patients in 3 after bradykinin

Two patients both with normal portal pressure were not examined with superior mesenteric angiography one patient had a hypernephroma and the other a pancreatic carcinoma

All celiac angiographies were performed with 40 ml Urografin 76 % which was injected at a mean rate of 13 2 ml/s (10 8–15 4)

The superior mesenteric angiographies were performed with 60 ml at a mean rate of 12 0 ml/s (10 4–13 6)

The film series were programmed as follows Celiac angiography 2/s for 2 to 3 s 1/s for 2 to 3 s and 1 every second or third second for 16 to 24 s Superior mesenteric angiography 2/s for 2 to 3 s and 1 every third second for 30 to 36 s The exposures and injection were registered with a Mingograf

Splenic size was calculated according to BLENDIS et coll (1969) as the area of the spleen i e the product of the length and width

Liver size was estimated and classified in degrees of 0 to 2 from normal to enlarged.

Dimensions of the vessels were estimated by measuring the diameters. The proper hepatic, the right and left hepatic, the splenic and the superior mesenteric arteries were measured one cm from the origin. The splenic, the superior mesenteric and the portal veins were measured one cm from the confluence.

Arterial flow. As a parameter for the arterial flow velocity in the liver, spleen and intestine, the emptying times of the arteries were determined. The arterial emptying time for a region is the time elapsing from the end of the injection to all arteries have emptied.

Venous flow. As a parameter for the venous flow velocity, the time from the start of the injection to maximum filling (maximum contrasting effect) of the splenic, superior mesenteric and portal veins was recorded.

Gallbladder. The time required for maximum accumulation of contrast medium in the wall of the gallbladder was also recorded, as well as its duration (UDÉN 1977).

Results

Portal pressure (17 cases)

The wedge hepatic venous pressure was measured in 14 patients and in 3 the portal pressure was measured at operation. Values up to 1.4 kPa are regarded as normal (KROOK) and were recorded in 6 patients. One patient with normal angiographic and clinical findings had a pressure of 1.6 kPa. In spite of this slightly increased pressure this patient has to be regarded as normal.

Increased values between 1.8 and 4.7 kPa (mean value 3.3 kPa) were recorded in 10 patients (Fig. 1), all having liver cirrhosis except one. This patient had thrombosis of liver veins, thus the wedge hepatic venous pressure could not be determined. The pressure measured at operation was 4.7 kPa.

Splenic size (17 cases)

The splenic area was in the cases with normal portal pressure 74 to 124 cm^2 (mean 101) and 110 to 392 cm^2 (mean 210) in the patients with portal hypertension. The highest value (392 cm^2) was found in a patient with biliary cirrhosis for more than 10 years.

A rather good correlation ($r = 0.78$) existed between the splenic size and the portal pressure (Fig. 1) if the patient with the extraordinary splenomegaly was excluded.

Splenic circulation (17 cases)

Mean circulation time. The arterial emptying time of the spleen varied between 1.4 and 6.0 s (mean 2.6). All patients had an emptying time within 4 s except one

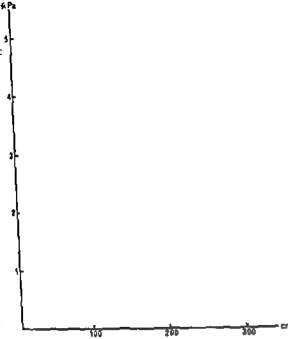


Fig 1 Splenic size compared to portal pressure (16 cases)

patient This patient had a very long and tortuous splenic artery with a small aneurysm and had an emptying time of 6 0 s

In 5 of the 7 patients without portal hypertension the maximum filling of the portal vein occurred between 7 5 and 9 8 s (mean 8 4) and the portal pressure was between 1 0 and 1 6 kPa (mean 1 2) In the two remaining patients with normal portal pressure the maximum filling of the portal vein occurred late at 11 4 and 15 4 s One was the patient with the long and tortuous splenic artery a small aneurysm and a prolonged emptying time The other patient had a carcinoma of the pancreas causing obstruction of the splenic artery and vein with collateral circulation via the gastroepiploic arteries and veins

In 8 of 10 patients with portal hypertension the portal vein was filled at celiac angiography The maximum filling occurred between 11 9 and 19 5 s (mean 14 7)

In the 2 remaining cases both with portal hypertension the portal vein was not filled from the splenic vein One of these had a pressure of 2 6 kPa and at the superior mesenteric angiography the splenic vein was filled in a retrograde direction In the last case with a pressure of 3 3 kPa portal branches were filled through arterioportal shunts A slight retrograde flow into the main portal vein was also recorded

No correlation (r – 0 23) existed between the emptying time of the spleen and the portal pressure and no correlation (r = 0 30) between the emptying time and the splenic size

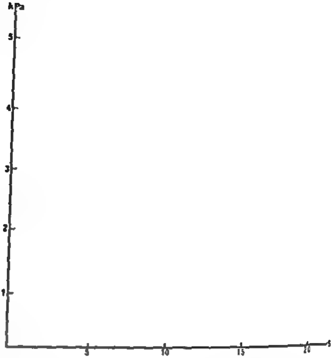


Fig 2 Time for maximum filling of portal vein at celiac angiography compared to portal pressure (13 cases)

The maximum filling of the portal vein could not be related to the portal pressure in 4 patients in 2 patients with portal hypertension without filling of the portal vein in the patient with the long and tortuous splenic artery and in the patient with the pancreatic carcinoma The 2 latter had a normal portal pressure but late filling of the portal vein

The mean circulation time and the portal pressure were directly correlated (r=0 96) in 5 patients with normal portal pressure and in 8 with portal hypertension (Fig 2)

Dimensions of vessels The diameter of the splenic artery varied between 6 and 8 mm (mean 7 0) in the cases with a normal portal pressure and between 7 and 12 mm (mean [illegible] 2) in those with portal hypertension The diameter of the splenic vein was 7 to 16 mm (mean 10 7) in the first group and 7 to 18 mm (mean 12 5) in the second group

In all patients the splenic vein was wider than the artery except in 2 cases with portal hypertension The splenic vein and the artery had the same diameter in one patient and in another the diameter of the splenic vein was slightly less than that of the artery In these 2 cases the flow in the splenic vein was decreased due to collateral flow from the spleen and the portal vein was not filled from the splenic vein In these 2 cases also a retrograde flow existed in the splenic or portal vein

The transverse area of the splenic artery was well correlated (r=0 91) to the splenic size The correlation between the area of the splenic vein and the splenic size was somewhat less (r=0 68) but higher (r=0 81) if the 2 cases with retrograde flow were excluded

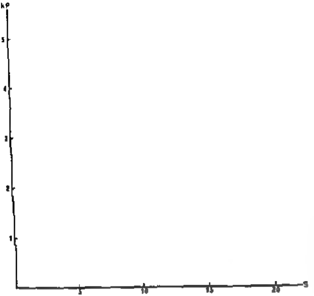


Fig. 3. Time for maximum filling of portal vein at superior mesenteric angiography compared to portal pressure (10 cases).

Superior mesenteric circulation (10 cases)

Superior mesenteric angiography was performed in 15 patients. Five patients were excluded, 3 of them because the angiography was performed after bradykinin which causes decreased circulation times and increased vessel diameters (BOIJSEN & REDMAN) and the 2 remaining cases due to technical reasons.

Mean circulation time. The maximum filling occurred at 13.3 to 18.7 s (mean 16.3) in the patients with normal portal pressure and at 14.4 to 19.3 s (mean 17.5) in the patients with portal hypertension (Fig. 3).

The maximum filling of the portal vein and the portal pressure did not correlate ($r = 0.54$) in these 10 cases.

Dimensions of vessels. The diameter of the superior mesenteric artery varied between 8 and 12 mm (mean 9.6) and the diameter of the superior mesenteric vein between 11 and 19 mm (mean 14.5). In patients with portal hypertension the diameters had a slight tendency towards being wider than in patients with normal portal pressure.

Hepatic circulation (17 cases)

Mean circulation time (16 cases). One case was excluded because of a spasm of the superior mesenteric artery which was the origin of the proper hepatic artery. The emptying time of the hepatic arteries was 1.4 to 5.2 s (mean 3.2).

No correlation ($r = 0.33$) existed between emptying time of the arteries of the liver

and the portal pressure The emptying time was also independent of the size of the liver

In 6 cases no difference was found between emptying time of the hepatic and splenic arteries In 7 cases the emptying time of the hepatic artery was longer than of the splenic artery, but in 6 of those the difference was not more than 2 s In one case with biliary cirrhosis the difference was 3 4 s

Three patients had longer emptying time of the splenic than of the hepatic arteries One patient with portal hypertension and arterioportal shunting had almost one second longer emptying time of the splenic than of the hepatic arteries the reason probably being the increased arterial hepatic flow caused by arterioportal shunting In 2 cases the emptying time of the splenic arteries was more than 2 seconds longer than that of the hepatic arteries One of them was the case with pancreatic carcinoma and occlusion of the splenic artery and the other the one with the long and tortuous splenic artery and aneurysm In both these cases comprehensible reasons for the slowing of the splenic flow existed

The difference between emptying time of the hepatic and splenic arteries was independent of the portal pressure

Dimensions of vessels The transverse area was calculated from the recorded diameter In the 7 cases with normal portal pressure the area of the right and left hepatic artery was between 17 and 89 mm (mean 37) In 10 patients with portal hypertension the area was between 58 and 134 mm (mean 82)

The area of the portal vein varied in the patients with normal portal pressure between 154 and 452 mm^2 (mean 293) and in the patients with portal hypertension between 133 and 380 mm^2 (mean 229)

In the comparison between the transverse area of the right and left hepatic artery and that of the portal vein (16 cases) the patient with pancreatic carcinoma was excluded because the splenic vein was occluded and the portal vein was only faintly filled

No correlation could be recorded between the area of the hepatic arteries and the area of the portal vein in the normal patients ($r = -0\ 42$) nor in the patients with portal hypertension ($r = -0\ 46$)

The area of the right and left hepatic artery and the portal pressure correlated roughly ($r = 0\ 64$) The patient with the pancreatic carcinoma had rather large hepatic arteries probably due to liver metastases However the portal pressure was normal A patient with acute thrombosis of liver veins and with very high portal pressure (4 7 kPa) had no evident abnormality of the hepatic arteries If these 2 cases are excluded the correlation is higher ($r = 0\ 83$ Fig 4)

At celiac angiography the area of the right and left hepatic artery and the time for maximum filling of the portal vein correlated roughly ($r = 0\ 69$) If the 2 cases with pancreatic carcinoma and thrombosis of the liver veins are excluded the correlation is somewhat higher ($r = 0\ 75$)

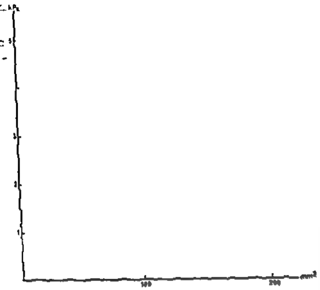


Fig 4 Transverse area of right and left hepatic artery compared to portal pressure (15 cases)

At superior mesenteric angiography no correlation existed between the area of the hepatic arteries and the time for maximum filling of the portal vein

Gallbladder circulation (10 cases)

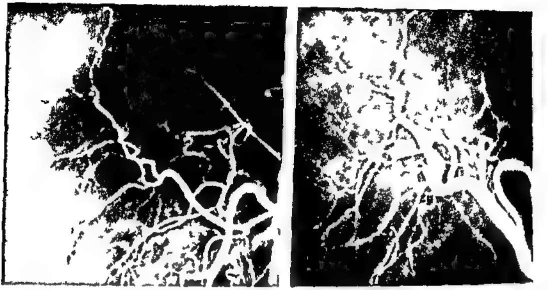
Accumulation of contrast medium in the wall of the gallbladder was recorded in 10 patients maximum occurred 5 6 to 9 0 s after the start of the *injection* The duration varied between 7 7 and 24 1 s Four patients with normal portal pressure had a duration varying between 11 4 and 13 4 s

In 2 other patients with normal portal pressure the duration was longer due to obstruction of the choledochal vein which is the draining vein of the gall bladder (UDEN 1972 *1976)* One of them with a duodenitis pancreatitis had a duration of 16 7 s and the other with a pancreatic carcinoma a duration *of 18 1* s Three *patients* with portal hypertension had a long duration from 15 9 to 24 1 s

One patient with portal hypertension had a *very short duration* (7 7 s) probably due to arterioportal shunting with a steal phenomenon

DISCUSSION

Selective visceral angiography is regarded by BOIJSEN & REDMAN among others as one of the best methods *for evaluating* changes in visceral blood flow Parameters such as circulation time and vessel diameter give information about blood flow in different parts of the viscera



a b

Fig. 5. a) Normal. Celiac angiography 1.7 s after injection. b) Liver cirrhosis with portal hypertension (3.1 kPa). Celiac angiography 1.6 s after injection. Increased arterial flow in the liver. In both cases peripheral arterial filling obtained. In (a) the arteries have normal transverse area, in (b) the arteries are widened indicating an increased arterial flow. The extent of arterial filling almost the same.

However, some sources of error must be taken into account: the hemodynamic effect of the contrast medium, of the catheter in selective angiography and of the pressure used at the injection of the medium.

It is generally agreed that contrast media cause vasodilatation, although some authors have reported no response or vasoconstriction. The hemodynamic effect of the catheter is small unless it has an outer diameter close to the inner diameter of the artery (BJORNO & PETTERSSON 1977). The effect of the pressure at the injection into the internal carotid artery has been carefully analysed by NORNES (1977). Only a slight increase in flow was observed in a few cases (4/13). The most frequent cause of flow changes was due to alterations in arterial blood pressure or ventilation.

Because of these errors true volumetric flow rate cannot be determined in absolute units. However, a good estimate of the flow rate can be obtained by recording transverse areas of vessels and flow velocity.

In order to record differences between the celiac and the superior mesenteric circulation regarding anatomy, shunts, retrograde flow and circulation times it is necessary to perform the angiography of these 2 arteries separately. If the examination is performed as a combined celiac and superior mesenteric angiography it is almost impossible to record differences in the 2 systems.

The present patients with portal hypertension had a transverse area of the hepatic arteries (mean 82 mm^2) which was about twice the diameter of the normal ones (mean 37 mm^2, Fig. 5). As the parameter for flow velocity, the emptying of

a b

Fig 6 a) Normal Celiac angiography Maximum filling of the portal vein 9 0 s after injection b) Liver cirrhosis with portal hypertension (3 1 kPa) Celiac angiography with maximum filling of the portal vein 14 3 s after injection Maximum contrasting effect of the portal vein and its branches is lower in (b) than in (a) and occurred 5 3 s later

the hepatic arteries did not differ between the 2 groups the arterial flow in the patients with portal hypertension has to be more than twice the arterial flow of the groups without portal hypertension This is due to the fact that the volumetric flow rate transverse area flow velocity Widened hepatic arteries in cirrhotic patients have previously been reported by REUTER et coll but they apparently did not record the circulation time

The increased arterial flow is most probably a compensation for the decreased portal flow in liver cirrhosis and is explained by the capacity of the liver for arterial autoregulation (KOCK et coll)

In normal case the contrasting effect of the portal vein is the same at celiac and superior mesenteric angiography but the time for maximum filling of the portal vein occurs later at superior mesenteric angiography

A decreased portal flow may find 2 different expressions as the volumetric flow is a product of transverse area and flow velocity either prolonged circulation time and a normal transverse area of the portal vein (Fig 6) or normal circulation time and a decreased transverse area of the portal vein which is more uncommon (Fig 7) At

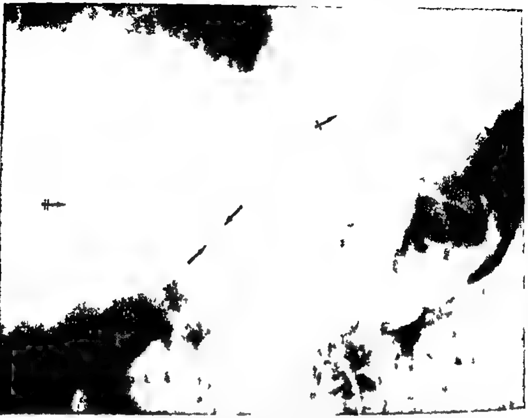
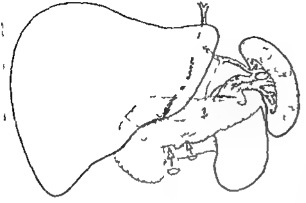


Fig. 7. Portal hypertension with large shunts. Superior mesenteric angiography. Maximum filling of the portal vein. Portal vein (→) relatively narrow indicating decreased portal flow which is due to a large portosystemic shunt to the coronary vein (↔), also shunting to the umbilical vein (↔).

celiac angiography in cases of portal hypertension the maximum filling of the portal vein occurred later (mean 14.7 s) than in normal cases (mean 8.4 s) and the contrasting effect of the vein was decreased (Fig. 6).

An explanation for this may be that the celiac system has possibilities of developing shunts. As a consequence of the shunting the flow passing the spleen will be diverted from the splenic vein to the shunts. Thus the flow reaching the portal vein is decreased (Fig. 8). In 2 cases with portal hypertension the portal vein did not fill from the splenic vein at celiac angiography due to retrograde flow. One case had arterio-portal shunting in the liver and the other had retrograde filling of the splenic vein from the superior mesenteric vein.

A direct correlation was found between the late filling of the portal vein at celiac angiography and the portal pressure. A correlation probably also exists between the shunted volume and the portal pressure as the explanation of the late filling of the portal vein is loss of flow by the shunts. However, the shunts may be difficult to detect on films, especially if they are small and have several locations. Even large shunts may be difficult to observe if they open up into a vein with a large flow, i.e. the left renal vein. Such shunts were found by GÖTHLIN (1976) in all patients (12) with



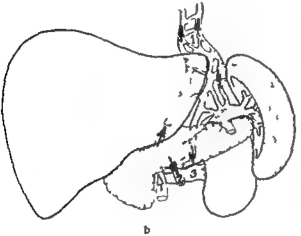


Fig 8 Celiac angiography Venous phase, 8 s after injection Schematic a) Normal case b) portal hypertension with portocaval shunting Shaded areas illustrate veins filled with contrast medium and correspond to equal volumes Blood mixed with contrast medium (closed arrows) blood without medium (open arrows) In (a) no blood flow to shunts in (b) flow to portocaval shunts by gastric and esophageal veins (1) inferior mesenteric (2) and left renal vein (3) As a consequence maximum filling of the portal vein occurs late

portal hypertension examined by a dye dilution technique He found a mean blood flow in the left renal vein of 840 ml/min in such patients and of 430 ml/min in normal cases i e an increased flow of 410 ml/min (6 8 ml/s) This is a very large volume considering that in a normal case the celiac flow is about 12 ml/s and normally about half of it is reaching the spleen Consequently the shunted volume in these cases is about the same as the normal splenic flow The transverse area of the splenic artery in the patients with portal hypertension was in mean 66 mm² and the area of the normal ones 38 mm² However the parameter for flow velocity the arterial emptying time was the same in the 2 groups Thus the splenic flow in patients with portal hypertension is nearly twice the flow in normal cases

At superior mesenteric angiography no difference in the time for maximum filling of the portal vein was found between the patients with normal portal pressure and those with portal hypertension The superior mesenteric circulation does not

have the same possibilities of developing portocaval shunts as the celiac system. Thus no obvious loss of flow to shunts appears and all the injected contrast medium has to pass through the portal vein.

Conclusions

(1) At celiac angiography a direct correlation exists between the time for maximum filling of the portal vein and the portal pressure. Vascular abnormalities such as stenosis, aneurysm and retrograde flow in the splenic or the portal vein have to be observed and considered.

(2) At superior mesenteric angiography no correlation exists between the time for maximum filling of the portal vein and the portal pressure.

(3) The arterial flow to the liver is positively correlated to the portal pressure. The hepatic arteries are widened in portal hypertension and the parameter for flow velocity is normal.

(4) A rough negative correlation exists between arterial flow to the liver and the portal venous flow. This is explained by the capacity of the liver for arterial autoregulation.

(5) The splenic size is related to portal pressure.

(6) The splenic size is strongly positively correlated to the transverse area of the splenic artery, but the correlation is weaker to the transverse area of the splenic vein. A narrow splenic vein indicates early loss of venous flow in the splenic region by shunts, for instance to the left renal vein.

SUMMARY

Visceral angiography was performed in 7 patients with normal portal pressure and in 10 with portal hypertension. Circulation times, size of vessels and portal pressure were determined. At celiac angiography a direct correlation was found between time for maximum filling of portal vein and portal pressure provided no vascular abnormalities existed. At superior mesenteric angiography such a correlation was not found, loss of flow by shunts in portal hypertension being one explanation. Portocaval shunts are common in the celiac system but uncommon in the superior mesenteric system.

ZUSAMMENFASSUNG

Eine viszerale Angiographie wurde bei 7 Patienten mit normalem und bei 10 Patienten mit erhöhtem Druck in der Vena porta vorgenommen. Zirkulationszeiten, Grösse der Gefässe und der Druck wurden bestimmt. Bei einer abdominalen Angiographie wurde eine direkte Korrelation zwischen der Zeit für die maximale Füllung der Vena porta und dem Druck gefunden, vorausgesetzt, dass keine vaskulären Veränderungen vorlagen. Bei der Angiographie der Arteria mesenterica superior fand sich keine derartige Korrelation, was damit zu erklären ist, dass Verlust des Blutflusses durch Shunts bei erhöhtem Druck in der Vena porta entsteht. Shunts zwischen der Vena porta und der Vena cava sind gewöhnlich im zöliakalem System, jedoch ungewöhnlich im oberen mesenterialem Gefässgebiet.

RESUME

Une angiographie viscérale a été effectuee chez 7 malades ayant une pression portale normale et chez 10 ayant une hypertension portale Les auteurs ont determiné les temps de circulation les dimensions des vaisseaux et la pression portale Au cours de l angiographie coeliaque ils ont trouve une correlation directe entre le delai d opacification maximale de la veine porte et la pression portale a condition qu il n existe pas d anomalies vasculaires Au cours de l angiographie de l artère mésentérique superieure ils n ont pas trouvé de correlation semblable ce qui s explique par une diminution du debit due à des shunts dans l hypertension portale Les shunts portaux-caves sont frequents dans le système coeliaque mais sont rares dans le système mésentérique superieur

REFERENCES

ABEATICI S and CAMPI L Sur les possibilités de l angiographie hepatique La visualisation du système portal Acta radiol 36 (1951) 383

BARR J W LAKIN C and ROSCH J Vasopressin and hepatic artery Invest Radiol 10 (1975) 00

BERGSTRAND I Splenoportography *In* Angiography second edition p 1029 Edited by H L Abrams Little Brown & Co Boston 1971

— and EKMAN C A Portal circulation in portal hypertension Acta radiol 47 (1957) 1

BJORNO L and PETTERSSON H Hydro and hemodynamic effects catheterization of vessels III Experiments with a rigid walled model Acta radiol Diagnosis 18 (1977) 1

BLENDIS L M WILLIAMS R and KREEL L Radiological determination of spleen size Gut 10 (1969) 433

BOIJSEN E and REDMAN H C Effect of bradykinin on celiac and superior mesenteric angiography Invest Radiol 1 (1966) 422

— EKMAN C A and OLIN T Coeliac and superior mesenteric angiography in portal hypertension Acta chir scand 126 (1963) 315

BOOKSTEIN J J APPELMAN H I WALTER J F FOLEY D TURCOTTE J G and LAMBERT M Histological venographic correlates in portal hypertension Radiology 116 (1975) 565

GOTHLIN J Spontaneous portorenal shunting in portal hypertension assessed by a dye dilution technique Acta radiol Diagnosis 17 (1976) 696

HALES M R ALLAN J S and HALL E M Injection corrosion studies of normal and cirrhotic liver Amer J Pathol 35 (1959) 909

HANSON K M and JOHNSON P C Local control of hepatic arterial and portal venous flow in the dog Amer J Physiol 211 (1966) 712

JOHNSON G DART C H PETERS R M and MACFIE J A Hemodynamic changes with cirrhosis of the liver Ann Surg 163 (1966) 692

KOCK N G HANHSLOSER P RODING B and SCHENK JR W G Interaction between portal venous and hepatic arterial blood flow An experimental study in the dog Surgery 72 (1972) 414

KROOK H Circulatory studies in liver cirrhosis Acta med scand (1956) Suppl No 318

NEBESAR R A and POLLARD J J Portal venography by selective arterial catherization Amer J Roentgenol 97 (1966) 477

NORNES H Internal carotid artery blood flow during cerebral angiography Neuroradiology 1? (1977) 219

REUTER S R BERK R N and ORLOFF M J An angiographic study of the pre and post operative hemodynamics in patients with side to side portocaval shunts Radiology 116 (1975) 33

UDÉN R Cholecystokinin pancreozymin in celiac and superior mesenteric angiography Acta radiol Diagnosis 12 (1972) 363

— Secretin and epinephrine combined in celiac angiography Acta radiol Diagnosis 1 (1976) 17

VIAMONTE M MARTINEZ L PARKS R E WARREN D and FOMON J J Liver shunts Amer J Roentgenol 102 (1968) 773

WARREN W D FOMON J J VIAMONTE M MARTINEZ L O and KALSER M Spontaneous reversal of portal venous blood flow in cirrhosis Surg Gynec Obstet 126 (1968) 315

WARREN W D FOMON J J VIAMONTE M and ZEPPA R Preoperative assessment of portal hypertension Ann Surg 165 (1967) 999

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PSEUDOTUMOR OF THE RENAL PELVIS CAUSED BY RENAL ARTERY ANEURYSM

L EKELUND E BOIJSEN and E LINDSTEDT

It is well known that normal renal arteries or their branches may bulge into the renal pelvis and calyces causing filling defects at urography (FRALEY 1962 KREEL & PYLE 1962 WEISSLEDER et coll 1962 BAUM & GILLENWATER 1966 GOLDSTEIN et coll 1974) Aneurysms may also cause impressions upon the renal pelvis with subsequent urographic differential diagnostic problems (MATHE 1948 GREEN et coll 1976 BOIJSEN & LINK 1977) In such cases angiography is the diagnostic procedure of choice in establishing the correct diagnosis Since such contrast defects may cause confusion and the condition seems to be less well known this report appeared to be motivated

Material and Methods

The material comprised 7 patients 2 males and 5 females aged 39 to 71 years Urography and nephroangiography were performed in all patients and additional ultrasound examination of the kidneys in 2 patients In one patient retrograde pyelography was performed as well

Results

The clinical and radiologic findings in the 7 patients are summarized in the Table Three patients presented with macroscopic hematuria while only one of the patients was hypertensive Two of the aneurysms were calcified At urography either a filling defect of or a mass effect upon the renal pelvis was demonstrated in all patients

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Table

Clinical and radiologic findings in 7 patients with renal artery aneurysms

Case No	Age and sex	Symptoms	Calcification	Urography	Angiography	Treatment
1	55 F	Urinary infection macr hematuria	–	10 mm contrast defect in R renal pelvis	10 mm aneurysm	Expectation
2	48 F	Flank pain mild hypertension	–	Contrast defect in R renal pelvis	Fusiform aneurysm	Expectation
3	44 F	Incidental finding	+	2 5 × 2 5 cm calcification in L hilum	2 5 × 2 5 cm aneurysm	Expectation unchanged for 6 years
4	71 M	Macr hematuria	–	4 cm mass displacing L renal pelvis	Avascular mass no aneurysm	Excision of thrombosed aneurysm
5	70 M	L flank pain macr hematuria	+	3 cm ring like calcification in L hilum	Slight arterial displacement no aneurysm	Excision of thrombosed aneurysm
6	39 F	R flank pain	–	Hilar mass partially obstr infundibulum of upper pole	3 × 3 5 cm aneurysm	Extirpation
7	50 F	Angiomyolipoma in contralateral kidney	–	Contrast defect in R renal pelvis	18 × 12 mm aneurysm	Ligation

A 55 year old female presented with acute pyelonephritis and macroscopic hematuria (Case 1) At urography a defect was found in the confluence part of the right renal pelvis and this finding was confirmed at a retrograde pyelography As the filling defect constituted a diagnostic problem and a tumor could not be ruled out angiography was carried out Selective angiography in a p and right posterior oblique projections suggested a hilar aneurysm which was however not demonstrated in detail In order to better demonstrate the anatomy of the aneurysm the patient was examined in the left posterior oblique projection with the beam directed 10 degrees cranially resulting in exact delineation of a hilar aneurysm 10 mm in diameter (Fig 1)

In one 48 year old woman with right sided flank pain and a mild hypertension a filling defect was observed at urography in the central part of the renal pelvis (Case 2) Selective angiography demonstrated this to be caused by a fusiform aneurysm (Fig 2)

A 2 5 cm × 2 5 cm large rounded calcification causing deformation of the left renal pelvis was incidentally found at urography in a 44 year old female with back

Fig 1 Case 1 a) Urography Contrast defect in confluence part of right renal pelvis suggesting tumor b c) Selective angiography of right kidney in a p and right posterior oblique projections Probably aneurysm in hilar region d) Selective angiography in left posterior oblique projection and beam direction 10 cranially The aneurysm is clearly demonstrated

Fig. 2. Case 2. a) Filling defect in right renal pelvis (→). b) Defect caused by fusiform aneurysm.

pain (Case 3). The suggestion of a renal artery aneurysm was confirmed at subsequent angiography (Fig. 3). This patient has remained asymptomatic and the calcified aneurysm has not changed during 6 years.

Differential diagnostic difficulties were encountered in a 71 year old man with macroscopic hematuria and a 4 cm large mass displacing the left renal pelvis at urography (Case 4). Ultrasound examination suggested a cyst and puncture was attempted. However, only old blood could be aspirated why angiography was performed showing an avascular mass displacing the arteries in the middle part of the left kidney. The patient was operated upon and a thrombosed aneurysm extirpated. During surgery it was necessary to ligate a major arterial branch and postoperative angiography demonstrated partial infarction of the kidney (Fig. 4). He has remained normotensive.

Another thrombosed aneurysm was observed in a 70 year old male with flank pain and macroscopic hematuria (Case 5, previously reported by LINDSTEDT & LUNDERQUIST 1974). Conventional films demonstrated a 3 cm ring like calcification in the upper part of the hilum of the left kidney deforming the renal pelvis. No angiographic abnormalities were present except for a slight displacement of arteries. A

a b

Fig 3 Case 3 a) Urography Annular thick calcification causing impression on confluence part of left renal pelvis b) Aneurysm proved by selective angiography This aneurysm has remained unchanged for 6 years

tentative diagnosis was changed from aneurysm to cortical adenoma As malignant tumor could not be excluded an operation was performed a thrombosed aneurysm excised and the artery repaired

In a 39 year old woman with back pain urography demonstrated a hilar mass on the right side partially obstructing the infundibulum of the upper pole (Case 6 previously reported by BOIJSEN & LINK) The mass seemed to be cystic at ultrasound but angiography revealed a 3 cm × 3 5 cm large right renal artery aneurysm and a smaller aneurysm on the left side The large renal aneurysm was repaired extra corporeally by microdissection and the kidney was reimplanted in the right pelvis

Finally in a 50-year old female with a left renal angiomyolipoma a 18 mm × 12 mm large non calcified renal artery aneurysm causing an impression on the right renal pelvis was found synchronously at angiography (Case 7) Nephrectomy was performed on the left side after that the right renal artery aneurysm had been ligated

Four of the 7 patients have thus been operated upon while one calcified aneurysm has remained unchanged for 6 years

Discussion

In a review of 50 consecutive aortographic films KREEL & PYLE found arterial impressions on the renal pelvis in 20 per cent All renal pelves were of the intrarenal type which is more intimately associated with the vascular pedicle of the kidney

a

b

c

Fig 4 Case 4 a) *Urography* Displacement of left renal pelvis b) Displaced arteries and avascular mass c) Angiography after extirpation of aneurysm and arterial ligation Partially infarcted kidney

Thus the renal artery and its branches can more easily cause impressions on the pelvis Furthermore BAUM & GILLENSWATER in a review of 100 consecutive cases of aortography and selective nephroangiography found that vascular impressions on the renal pelvis in 42 per cent caused filling defects as demonstrated at urography

and retrograde pyelography Also in this review all cases of filling defects due to arterial impressions had pelves of the intrarenal type

Another appearance is a discrete notch like impression on the renal pelvis which may closely resemble a tumor GOLDSTEIN et coll described 4 patients with such filling defects which were initially considered clinically and radiographically to represent neoplasms but subsequent angiography confirmed the vascular cause A clue to the vascular origin of these defects is often provided by the application of abdominal compression in conjunction with urography which tends to minimize or obliterate a vascular impression

As a rule these vascular impressions are of no clinical significance except from a differential diagnostic point of view However extrinsic obstruction of the superior infundibulum caused by renal vessels producing flank pain has been described by FRALEY

Filling defects of the renal pelvis caused by renal artery aneurysm may also create differential diagnostic problems This has received little attention in the angiographic literature Cases have been described by MATHE for example where deformation had been originally ascribed to a tumor but at surgery proved to be a hilum aneurysm GREEN et coll recently reported on a young female with acute flank pain and micro scopic hematuria in whom a 3 cm mid pelvic renal mass was found at urography Ultrasound examination in this case demonstrated two small echo free renal masses meeting all criteria for cyst while angiography revealed two saccular renal artery aneurysms These authors emphasized that echo free renal masses are not always simple cysts and that it is insufficient to rely solely on ultrasound examination A similar case was recently described by BOIJSEN & LINK (Case 6 in the present series) At urography a hilar mass was found on the right side which seemed to be cystic on ultrasound At angiography performed before puncture because of the hilar loca tion of the mass a 3 cm × 3 5 cm renal artery aneurysm was found to be responsible for the mass This clearly demonstrates the value of angiography before puncture of a hilar mass as aneurysm puncture obviously would be dangerous

Aneurysms of the renal artery usually have a hilar location and therefore accurate demonstration of their anatomy may be difficult due to superimposition of arteries In such instances the contralateral oblique projection in combination with an angula tion of the roentgen tube may prove helpful as illustrated in Fig 1

Two of the present aneurysms were calcified These calcifications were of the annular type that has been regarded as typical for renal artery aneurysm (BOIJSEN & KÖHLER 1963) POUTASSE (1966) summarized his experience with 57 surgical cases of renal artery aneurysms 18 (32) being calcified GLASS & USON (1967) reviewed the findings in 20 patients with renal artery aneurysms In 24 separate aneurysms 12 (50) were calcified Urography was performed in 15 patients in 4 classical ring formed calcification at the renal hilum was found Some calcified aneurysms contain only small calcific deposits and may then be erroneously considered as renal calculi The common opinion is that calcified aneurysms are not likely to rupture (IPPOLITO &

LE VEEN 1960) while HARROW & SLOANE (1959) found the incidence of rupture in 100 cases of non calcified aneurysm to be approximately 25 per cent (one quarter of these occurred in pregnant women, indicating that the danger of rupture is significant in this condition). One of the present calcified aneurysms (Case 3) has been followed for 6 years and has remained unchanged as considered at repeat urographies.

In 5 of the present cases the renal artery aneurysm was readily demonstrated by angiography. However, in cases of completely thrombosed aneurysms angiography may only show an avascular lesion with displacement of vessels as in 2 of the present cases (Nos 4, 5). In such cases angiographic differential diagnosis includes cyst or avascular tumor and exploration may be necessary in order to reveal the true nature of the lesion. In Case 4 ultrasound examination suggested a cyst thus making this case similar to Case 6. Renal artery aneurysms must therefore be included in the differential diagnosis of echo free renal masses as has already been emphasized by GREEN et coll. and BOIJSEN & LINK.

SUMMARY

Urographic abnormalities caused by renal artery aneurysms are discussed on the basis of seven cases. Angiography is the diagnostic procedure of choice to make the correct diagnosis. In cases of completely thrombosed aneurysms angiography may only demonstrate an avascular mass with displacement of vessels. At ultrasound examination renal artery aneurysms should be included in the differential diagnosis of echo free renal masses.

ZUSAMMENFASSUNG

Anhand von sieben Fällen werden die Befunde diskutiert, die bei der urographischen Untersuchung von Patienten mit einem Aneurysma der Nierenarterie zur Darstellung kamen. Die diagnostische Methode der Wahl zur korrekten Diagnosestellung ist die Angiographie. Bei Vorliegen eines vollständig thrombotisierten Aneurysmas kann sich bei der Angiographie ausschliesslich ein avaskulärer raumfordernder Prozess mit Verlagerung benachbarter Gefässe finden. Bei der Ultraschalluntersuchung sollten Aneurysmen der Nierenarterie in die Differentialdiagnose echofreier raumfordernder Prozesse der Niere einbezogen werden.

RÉSUMÉ

Les auteurs étudient les anomalies urographiques causées par les anévrysmes de l'artère rénale en se basant sur sept cas. L'angiographie est la méthode diagnostique de choix pour faire un diagnostic correct. Dans les cas d'anévrysme complètement thrombosé l'angiographie ne peut mettre en évidence qu'une masse avasculaire avec déplacement des vaisseaux. Au cours de l'examen échotomographique, on devrait inclure les anévrysmes de l'artère rénale dans le diagnostic différentiel des masses rénales non échogènes.

REFERENCES

BAUM S and GILLENSWATER J Y Renal artery impressions on the renal pelvis J Urol 95 (1966) 139

BOIJSEN E and KOHLER R Renal artery aneurysms Acta radiol Diagnosis 1 (1963) 1077

— and LINK H P Arteriography before needle puncture of renal hilar lesions J Urol 118 (1977) 237

FRALEY E E Surgical correction of intrarenal disease Obstructions of the superior infundibulum J Urol 98 (1962) 54

GLASS P M and USON A C Aneurysms of the renal artery A study of 20 cases J Urol 98 (1967) 285

GOLDSTEIN H M REUTER S R and WALLACE S Pseudotumor of the renal pelvis caused by arterial impression J Urol 111 (1974) 735

GREEN W M KING D L and CASARELLA W J A reappraisal of sonolucent renal masses Radiology 121 (1976) 163

HARROW B R and SLOANE J A Aneurysms of renal artery Report of five cases J Urol 81 (1959) 35

IPPOLITO J J and LE VEEN H H Treatment of renal artery aneurysms J Urol 83 (1960) 10

KREEL L and PYLE R Arterial impressions on the renal pelvis Brit J Radiol 35 (1962) 609

LINDSTEDT E and LUNDERQUIST A Renal arterial aneurysm not detectable on angiography A case report J Urol 112 (1974) 302

MATHÉ C P Aneurysm of the renal artery Report of five cases one treated by resection of aneurysmal sac without sacrificing the kidney J Urol 60 (1948) 543

POUTASSE E F Renal artery aneurysms Their natural history and surgery J Urol 95 (1966) 297

WEISSLEDER H EMMRICH J und SCHIRMESTER J Gefassbedingte Kontrastmittelaussparungen im urographischen Bild Fortschr Rontgenstr 97 (1962) 703

LE VEEN 1960), while HARROW & SLOANE (1959) found the incidence of rupture in 100 cases of non calcified aneurysm to be approximately 25 per cent (one quarter of these occurred in pregnant women indicating that the danger of rupture is significant in this condition). One of the present calcified aneurysms (Case 3) has been followed for 6 years and has remained unchanged as considered at repeat urographies.

In 5 of the present cases the renal artery aneurysm was readily demonstrated at angiography. However, in cases of completely thrombosed aneurysms angiography may only show an avascular lesion with displacement of vessels as in 2 of the present cases (Nos 4, 5). In such cases angiographic differential diagnosis includes cyst or avascular tumor and exploration may be necessary in order to reveal the true nature of the lesion. In Case 4 ultrasound examination suggested a cyst thus making the case similar to Case 6. Renal artery aneurysms must therefore be included in the differential diagnosis of echo free renal masses as has already been emphasized by GREEN et coll. and BOIJSEN & LINK.

SUMMARY

Urographic abnormalities caused by renal artery aneurysms are discussed on the basis of seven cases. Angiography is the diagnostic procedure of choice to make the correct diagnosis. In cases of completely thrombosed aneurysms angiography may only demonstrate an avascular mass with displacement of vessels. At ultrasound examination renal artery aneurysms should be included in the differential diagnosis of echo free renal masses.

ZUSAMMENFASSUNG

Anhand von sieben Fällen werden die Befunde diskutiert, die bei der urographischen Untersuchung von Patienten mit einem Aneurysma der Nierenarterie zur Darstellung kamen. Die diagnostische Methode der Wahl zur korrekten Diagnosestellung ist die Angiographie. Bei Vorliegen eines vollständig thrombosierten Aneurysmas kann sich bei der Angiographie ausschliesslich ein avaskulärer raumfordernder Prozess mit Verlagerung benachbarter Gefässe finden. Bei der Ultraschalluntersuchung sollten Aneurysmen der Nierenarterie in die Differentialdiagnose echofreier raumfordernder Prozesse der Niere einbezogen werden.

RESUME

Les auteurs étudient les anomalies urographiques causées par les anévrysmes de l'artère rénale en se basant sur sept cas. L'angiographie est la méthode diagnostique de choix pour faire un diagnostic correct. Dans les cas d'anévrysme complètement thrombosé l'angiographie ne peut mettre en évidence qu'une masse avasculaire avec déplacement des vaisseaux. Au cours de l'examen échotomographique on devrait inclure les anévrysmes de l'artère rénale dans le diagnostic différentiel des masses rénales non échogènes.

REFERENCES

BAUM S and GILLENSWATER J Y Renal artery impressions on the renal pelvis J Urol [redacted] (1966) 139

BOIJSEN E and KÖHLER R Renal artery aneurysms Acta radiol Diagnosis 1 (1963) 1077

— and LINK D P Arteriography before needle puncture of renal hilar lesions J Urol 118 (1977) 237

FRALEY [redacted] E Surgical correction of intrarenal disease Obstructions of the superior infundibulum J Urol 98 (1967) 54

GLASS P M and USON A C Aneurysms of the renal artery A study of 20 cases J Urol 98 (1967) 785

GOLDSTEIN H M REUTER S R and WALLACE S Pseudotumor of the renal pelvis caused by arterial impression J Urol 111 (1974) 735

GREEN W M KING D L and CASARELLA W J A reappraisal of sonolucent renal masses Radiology 121 (1976) 163

HARROW B [redacted] and SLOANE J A Aneurysms of renal artery Report of five cases J Urol 81 (1959) 35

IPPOLITO J J and LE VEEN H H Treatment of renal artery aneurysms J Urol [redacted] (1960) 10

KREEL L and PYLE R Arterial impressions on the renal pelvis Brit J Radiol 35 (1967) 609

LINDSTEDT E and LUNDERQUIST A Renal arterial aneurysm not detectable on angiography A case report J Urol 112 (1974) 302

MATHÉ C P Aneurysm of the renal artery Report of five cases one treated by resection of aneurysmal sac without sacrificing the kidney J Urol 60 (1948) 543

POUTASSE E F Renal artery aneurysms Their natural history and surgery J Urol 95 (1966) 297

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Table

Comparison between endoscopic and radiologic findings of the stomach

	Endoscopy	Radiology	
		False neg	False pos
Stomach			
Ulcer	9	1 (1)	1
Scar	8	2 (1)	0
Carcinoma	2	0	1
Polyps	14	3 (3)	1
Duodenum			
Ulcer	7	0	0
Scar	[illegible]	1	0
Total	47	7 (5)	3

* Identified at retrospective examination

Radiologic error rate $\frac{7-3}{10}$ = [illegible] per cent

20 patients with butylscopolaminbromide (Bulamin Medica) 20 mg intravenously and in the remainder with glucagon (Glucagon Novo) 1 mg intravenously. The contrast medium 50 to 90 ml Barytgen de luxe (Fushimi Pharmaceutical Co.) was introduced via the tube. The air was pumped using a rubber pump until the distension on fluoroscopy seemed to be sufficient and the mucosal folds had disappeared. The patient was turned on a horizontal couch from side to side for good mucosal coating. Films were obtained in prone, supine and erect positions. Exposure times were automatically adjusted and the tube potential was 90 kV.

The radiographic findings were classified according to the endoscopic results as (a) false negatives: pathologic findings at endoscopy not observed at radiography or (b) false positives: pathologic radiographic findings not found on endoscopy. The final results were analysed with uniform criteria after the whole series was completed.

Results

The films were evaluated to determine the quality of the examination (good, adequate, poor). The following criteria were applied: appearance of the areae gastricae (Fig. 1), flocculation of the contrast material, air bubbles and possible poor demonstration of the duodenal bulb. The results were good in 84 cases and adequate in 18 cases. In 2 the areae gastricae were not visible, air bubbles disturbed 11 examinations and satisfactory films of the duodenal bulb were not obtained in 3 cases. Flocculation occurred in 2 cases. The comparison of the endoscopic and radiologic

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DOUBLE CONTRAST EXAMINATION OF THE STOMACH COMPARED WITH ENDOSCOPY

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The double contrast examination introduced by Japanese authors is being increasingly used for the examination of the stomach The method is especially sensitive for evaluating the gastric mucosal lesions and early malignant gastric tumours (SHIRAKABE 1972) Its advantages have been reported in many articles and the diagnostic accuracy has been claimed to be better than in examinations with the conventional barium technique However, MONTAGNE et coll (1978) found almost the same rate of errors in both the conventional and the double contrast examinations

In the prospective series now reported the results obtained by double contrast examination of the stomach were compared with the endoscopic findings The films were analysed without knowledge of the clinical or endoscopic data

Material and Methods

The material consisted of 102 patients admitted to the gastroenterologic department at this hospital Cases for the roentgen examination were chosen before endoscopy which was performed using the end viewing Olympus GIF K D2 or D3 panendoscope The radiography was carried out on the following day

The double contrast examination was slightly modified consisting of nasogastric intubation and hypotonia Possible secretion was eliminated before the contrast medium was introduced Hypotonia of the stomach and duodenum was achieved in

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n the films This last group of polyps was excluded from the comparison because a ifferentiation between these small polyps and small air bubbles was uncertain

False positive findings occurred in 3 cases In one case a radiographically suggested astric ulcer was not observed at endoscopy In the second case a scirrhous carcinoma as suggested on the basis of a constant antrum rigidity in the films However iopsy showed atrophic gastritis and at a later radiographic examination the stomach xpanded In the third case a suggested polyp of over 0 5 cm in diameter was probably thick mucosal fold

A few of the original reports led to additional examinations The reliability of ndoscopy based upon radiographic findings was not tested However one sug gested duodenal ulcer could not be confirmed at endoscopy because the endoscope did not pass the pylorus In another case an ulcer scar in the fornix was at first not located at endoscopy but at a second endoscopy the scar was confirmed

Discussion

In the past few years endoscopy has become a well-established procedure for xamining the upper gastrointestinal tract Gastroscopy has indicated that the con entional barium method may be a relatively poor procedure for achieving the correct diagnosis Conventional radiography has been shown to be erroneous in 20 to 30 per cent of cases (COTTON 1973 LAUFER et coll 1975 STENDER et coll 1975) causing some endoscopists to doubt its value (KOBLER et coll 1976) However greater ac curacy has been achieved with the double contrast examination Most reports on the accuracy of the double contrast examination are based on a retrospective analysis The present investigation is a prospective one and the results have been analysed without knowledge of other data A similar critical investigation has been made by MONTAGNE et coll A serious disadvantage of this type of comparison is that the accuracy of one method radiography is tested by another method endoscopy The evaluation of the two methods should be based on a third objective test The radio logic error rate of the double contrast examination has been estimated to 6 to 11 per cent (LAUFER 1975 LAUFER et coll HERLINGER et coll 1977) and in the present report it is 10 per cent In the present series based on endoscopy possible erroneous evaluation at endoscopy may have influenced the results In addition the gastroscopist had all the clinical and previous radiologic information before the endoscopy in contrast to the radiologist

With the double contrast method even minute mucosal abnormalities can be demonstrated in contrast to the conventional barium examination e g early gastric tumour (YAMADA & ICHIKAWA 1974 KOGA et coll 1975) With the conventional method polyps often are not observed In the present series polyps over 0 5 cm in diameter were usually detected but smaller polyps were difficult to distinguish from air bubbles due to the relative lack of antifoaming agent in the contrast medium This can be avoided by adding extra simethicone Identification of even small polyps

Fig 1

Fig 2

Fig 1 Areae gastricae of the antrum well demonstrated as are two polyps

Fig 2 Posterior wall of the fornix with mucosal folds converging upon an ulcer scar Mul p[...] erosions in the lower part of the stomach (→)

findings is presented in detail in the Table According to the endoscopic findings total of 7 per cent false negatives and 3 per cent false positives were encountered i[...] the series Identical results were obtained on endoscopy and radiography in 90 p[...] cent of the cases Thus the radiologic deviation from endoscopy was 10 per cent

The false negatives were the following One ulcer (malignant at biopsy) and ulcer scars were not demonstrated with the double contrast method However at retrospective examination of the films the ulcer and one of the scars were identifie[...] they had been overlooked at the initial reporting Of the 14 polyps found at end[...] scopy over 0 5 cm in diameter 11 were initially observed and the remainder ret[...] spectively of those less than 0 5 cm in diameter 14 were found at endoscopy and

SUMMARY

The results of the double contrast examination of the stomach in a series of 102 patients ere compared with the findings at endoscopy Nasogastric intubation was used to in oduce the air into the stomach Hypotonia was achieved mainly with glucagon The radiogic error rate was 10 per cent consisting of 7 per cent false negative and 3 per cent false ositive findings The diagnostic advantages of the double contrast technique over those of e conventional barium examination are discussed

ZUSAMMENFASSUNG

Die Resultate von Doppelkontrast Untersuchungen des Magens wurden in einer Serie on 102 Patienten mit den Befunden der Endoskopie verglichen Eine nasogastrische In ubation wurde verwendet um Luft in den Magen einzufuhren Hypotonie wurde haupt achlich mit Glukagon erreicht Die rontgenologische Fehlerrate betrug 10 Prozent be tehend aus 7 Prozent falsch negativen und 3 Prozent falsch positiven Befunden Die diagnotischen Vorteile der Doppelkontrast Technik gegenuber denen der gewohnlichen Barium Untersuchung werden diskutiert

RESUMÉ

Les auteurs ont comparé les résultats de l examen en double contraste de l estomac sur une série de 102 patients avec les résultats de l endoscopie Ils ont utilise l intubation nasogastrique pour introduire l air dans l estomac Ils ont obtenu l hypotonie gastrique le plus souvent au moyen du glucagon Le taux d erreurs radiologiques a été de 10 pour-cent consistant en 7 pour-cent de faux négatifs et 3 pour-cent de faux positifs Les avantages diagnostiques de la technique en double contraste sur ceux de l examen baryté traditionnel sont etudiés

REFERENCES

BLOOM S M PAUL R E MATSUE H POPLACK W E and GOLDSMITH M R Improved radiographic detection of multiple gastric ulcers Amer J Roentgenol 128 (1977) 949

COTTON P B Fibreoptic endoscopy and the barium meal—results and implications Brit med J 2 (1973) 161

GOLD R P and SEAMAN W B The primary double-contrast examination of the post operative stomach Radiology 124 (1977) 297

HERLINGER H GLANVILLE J N and KREEL L An evaluation of the double contrast barium meal (DCBM) against endoscopy Clin Radiol 28 (1977) 307

HUNT J H and ANDERSON I F Double contrast upper gastrointestinal studies Clin Radiol 27 (1976) 87

KOBLER E DEYHLE P und NUESCH H Magenulcus Nicht erst Rontgen — gleich Endoskopie und Biopsie Med Trib 13 (1976) 24

KOGA M NAKATA H KIYONARI H INAKURA M and TANAKA M Roentgen features of the superficial depressed type of early carcinoma Radiology 115 (1975) 289

LAUFER I A simple method for routine double-contrast study of the upper gastrointestinal tract Radiology 117 (1975) 513

— MULLENS J E and HAMILTON J The diagnostic accuracy of barium studies of the stomach and duodenum—correlation with endoscopy Radiology 115 (1975) 569

is of great importance, because some of them can be or become malignant (ROSATO & NOTO 1966) A clear correlation between the size and the shape of polyps and their malignancy has also been noticed radiologically (SHIRAKABE) Possible malignant features of the lesion must be demonstrated both on profile and en face views With the double contrast method erosive gastritis may also be diagnosed (FIG 2) Thus TRAGÅRDH et coll (1978) demonstrated complete gastric erosions in 21 of 33 cases with a time span of less than one month between radiography and gastroscopy and in 4 of 13 cases with a time span of 1 to 3 months On the other hand small surface erosions not associated with surrounding mucosal swelling usually go unnoticed Multiple, linear or rod shaped ulcers are well demonstrated by the double contrast method (BLOOM et coll 1977 POPLACK et coll 1977) Also postoperative stomachs can be more accurately examined by this method than with the conventional barium technique (GOLD & SEAMAN 1977) Acute upper gastrointestinal bleeding may be more precisely located by using the double contrast than the conventional barium technique (STEVENSON et coll 1976)

Hypotonia in conjunction with the double contrast method has clear advantages (HERLINGER et coll) It prevents the contrast material from passing too early to the duodenum and a spasm can be differentiated from a true wall lesion The drugs may also reduce the gastric secretion The side effects of glucagon are few and therefore it can also be used on out patients (MILLER et coll 1974) The amount of glucagon sufficient to produce gastric hypotonia is somewhat less (0 25–0 50 mg) than the amount used in the present series (MÄKELÄ et coll 1978)

The gaseous distension of the stomach must be in proportion to the size of the stomach By sucking the contrast medium through a straw with holes enough air may be carried with the medium into the stomach (MOHAMMED & HEGEDUS 1977) Powders or pills containing sodium bicarbonate release carbon dioxide when mild acid is used The amount of air in the stomach is best controlled by a nasogastric tube LINTOTT et coll (1978) suggested the following measurements as indicative of a good distension gastric fornix 10 cm corpus 7 cm and duodenum 4 cm However the gastric volumes vary and the amount of air must be adjusted individually

The diagnostic accuracy of the double contrast examination of the stomach is by most authors supposed to be superior to the conventional barium examination However MONTAGNE et coll still recommend that both the conventional and the double contrast examination should be performed It has been suggested that the double contrast method should be a primary examination even in routine work (HUNT & ANDERSON 1976) If necessary the examination may be completed by giving the patient thinner barium sulfate and thereafter exposing extra films Using a nasogastric tube possible secretion can be removed from the stomach and the examination can be performed under better control However carbon dioxide releasing pills or powders are more convenient for the patient and less time consuming

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INFLUENCE OF CONTRAST MEDIA OSMOLALITY ON ISOLATED RABBIT HEART PERFORMANCE

S BONGRANI G BALDI F CUCCHINI M DI DONATO and O VISIOLI

Previously (DI DONATO et coll 1978) the effect of contrast media on the cardiac contractility in the dog has been reported Hyperosmotic contrast agents increased the contractility This effect could be related either to the circulatory disturbances occurring after the injection or to an intrinsic effect of these agents The increase in contractile indices (Vce max Vmax) strongly suggested that an effective increase in contractile force occurred

The experiments now reported were carried out in isolated rabbit hearts working in isometric conditions to determine whether the peripheral circulation had any influence on the contractility increase In order to evaluate the significance of hyperosmolality on inotropic response two contrast media were compared the first commonly used (Urografin 76) the second a new non ionic low osmolality medium (Iopamidol 370) Contrast media were also injected in some hearts perfused with Propranolol and Cimetidine to evaluate the possible role of catecholamines and histamine release on an inotropic effect

Material and Methods

Twelve isolated rabbit hearts perfused by the Langerdorff technique were used The rabbits weighing 2 to 3 kg were killed by a sharp blow on the head Their hearts were rapidly removed mounted on a Langerdorff perfusion apparatus and imme

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LINTOTT D J SIMPKINS K C DE DOMBAL F T and NOAKES M J Assessment of the double contrast barium meal method and application Clin Radiol 29 (1978) 313

MAKELA P ROSSI I and KORMANO M Effect of glucagon on the double contrast examination of the stomach and duodenum Fortschr Rontgenstr 129 (1978) 418

MILLER R E CHERNISH S M SKUKAS J ROSENAK B D and RODDA B E Hypotonic roentgenography with glucagon Amer J Roentgenol 121 (1974) 264

MOHAMMED S H and HEGEDÜS V Double contrast examination of the stomach Acta radiol Diagnosis 18 (1977) 249

MONTAGNE J P MOSS A and MARGULIS A Double blind study of single and double contrast upper gastrointestinal examinations using endoscopy as a control Amer J Roentgenol 130 (1978) 1041

POPLACK W PAUL JR R E GOLDSMITH M MATSUE H BLOOM S MOORE J P and NORTON R A Linear and rod shaped peptic ulcers Radiology 122 (1977) 317

ROSATO F E and NOTO J A Gastric polyps Amer J Surg 111 (1966) 647

SHIRAKABE H Double contrast studies of the stomach Georg Thieme Verlag Stuttgart 1972

STENDER H S SEIFERT E LUSKA G und OTTO P Vergleichende rontgenologische und endoskopische Diagnostik des Ulcus ventriculi und duodeni Fortschr Rontgenstr 122 (1975) 381

STEVENSON G W COX R R and ROBERTS C J Prospective comparison of double-contrast barium meal examination and fibreoptic endoscopy in acute upper gastrointestinal haemorrhage Brit med J 2 (1976) 723

TRAGÅRDH B WEHLIN L and OHASHI K Radiologic appearance of complete gastric erosions Acta radiol Diagnosis 19 (1978) 634

YAMADA T and ICHICAWA H X ray diagnosis of elevated lesions of the stomach Radiology 110 (1974) 79

Table (*cont*)

lucose solution same osmolality as Jrografin 76*			Glucose solution same osmolality as Iopamidol 370		
Basal value	0–30 s	60 90 s	Basal value	20–30 s	60 90 s
48 9 ±3 9	3 1 ± 5	6? 7 ±4 4	43 3 ±3 7	39 0 ±3 5	47 1 ±3 9
1?8 4 ±7 9	11_9 ±6 3	143 3 ±9 8	131 6 ±8 0	1_7 ±6 6	141 0 ±9 _
49 3 ±7 ?	?1 8 ±3 *	51 0 ±8 2	40 6 ±7 7	1 7 ±3 8	53 9 ±8 7
710 0 ±43 3	367 0 ±?3 3	960 5 ±63 7	683 3 ±41 3	561 7 ±?9 8	791 9 ±50 2
5 7 ±2.7	34 0 ± 6	66 1 ±4 8	52 7 ±? 7	46 3 ±2 5	58 7 ±4 7
99 1 ±4 9	50 _ ±10 4	128 3 ±8 8	91 0 ±5 7	8? 7 ±6 9	101 1 ±7 0

Table 2

*Differences between the maximum changes induced by the various substances LVSP = left ventricular systolic pressure HR heart rate CPP = coronary perfusion pressure F test * = p < 0.05 ** = p < 0.01 n s = not significant*

		Iopamidol–Urografin	Urografin glucose solution with same osmolality	Iopamidol–glucose solution with same osmolality
LVSP	Decrease	11 48	4 72 n s	3 72 n s
	Increase	10 03	3 25 n s	3 08 n s
HR	Decrease	1 15 n s	1 07 n s	1 39 n s
	Increase	1 75 n s	4 32 n s	1 27 n s
CPP	Decrease	4 35 n s	3 08 n s	1 55 n s
dP dt	Decrease	11 73	4 53 n s	74 n s
	Increase	10 07	4 03 n s	3 19 n s
Vce max	Decrease	11 07*	4 08 n s	3 97 n s
	Increase	11 79	4 _5 n s	3 58 n s
Vmax	Decrease	1? 03	4 37 n s	4 85
	Increase	11 72	3 95 n s	2 75 n s

Table 1

*Mean basal values ± SE and maximum changes observed at 20 to 30 s and at 60 to 90 s after in[illegible] for each substance and for each parameter LVSP = left ventricular systolic pressure HR [illegible] CPP = coronary perfusion pressure Paired Student s t test * = p<0.05 ** = p<0.01 *** p<0.0[illegible]*

	Urografin 76®			Iopamidol 370		
	Basal value	20 30 s	60-90 s	Basal value	20-30 s	60-90 s
LVSP	43.5 ±3.2	12.6 ±1.0***	54.3 ±4.5**	45.1 ±4.0	38.9 ±3.8**	48.5 ±5.9
HR	113.8 ±6.9	102.6 ±5.7**	117.7 ±7.7*	120.7 ±7.6	105.1 ±6.8*	[illegible] 7.4
CPP	54.5 ±7.1	16.3 ±3.4***	49.6 ±7.8*	55.9 ±7.8	25.3 ±5.0***	47.5 ±8.0*
dP/dt	745.7 ±40.8	256.1 ±11.1**	1 003.6 ±74.5*	693.2 ±42.1	530.4 ±27.2*	79[illegible] ±48.1[illegible]
Vce max	57.7 ±2.6	21.6 ±2.1**	73.4 ±4.6**	55.8 ±2.4	45.6 ±2.0**	66.6 ±3.[illegible]
Vmax	100.4 ±5.6	37.6 ±4.5**	135.4 ±6.9*	98.5 ±5.3	72.6 ±7.0**	115.6 [illegible]

diately perfused through the aorta with the following solution (mmol/l) NaCl 136.9 KCl 2.68 CaCl 2H O 1.7 MgCl 6H O 0.99 NaHCO$_3$ 3.93 NaH PO$_4$ 0.4[illegible] glucose 5.55 The perfusion fluid was kept at 37 C and continuously perfused only with O The solution had pH 7.4 Perfusion was provided by a peristaltic pump (Watson Marlowe MHRE 22) at a rate of 16 to 18 ml/min

A fluid filled balloon (FALLEN et coll 1967) was inserted into the left ventricular chamber for pressure recording (on a Statham transducer P23Db) during isovolumic contraction Furthermore another pressure transducer (Statham P23Db) was connected to the side arm of the perfusing cannula for coronary perfusion pressure monitoring

Both pressures were recorded on a HP 7702 B The left ventricular pressure curves were then stored on an analog tape recorder (HP 3960) for successive continuous analysis by a HP 2100 computer

The program (COLLA et coll 1974) provided on a plotter and on a line printer the following parameters heart rate, left ventricular diastolic pressure left ventricular systolic pressure dp/dt and contractile indices (Vce max and Vmax from developed pressure)

The following substances were injected directly into the perfusing cannula in a

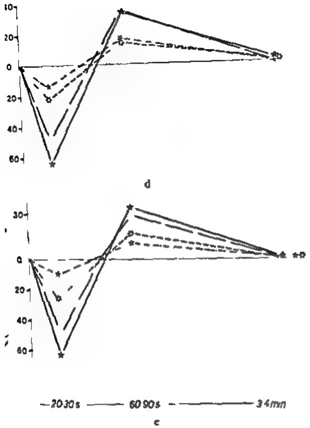

Fig 1 (For legend see opposite page)

Statistical analysis A paired Student s t test was done in order to compare the changes between basal values and the maximum effect observed in all parameters after each injection (Table 1) and a variance analysis was performed in order to evaluate the significance of the difference between the cardiovascular changes induced by Iopamidol Urografin and their iso osmolal glucose solutions

Three different analyses were performed between the two contrast media and between each contrast medium and its iso-osmolal glucose solution For each analysis a randomized block factorial design 2×2 was assumed the substances as first factor the base-effect association as second factor This analysis provided three F tests and because of the equality of the basal values only the interaction of the factors was considered (Table 2)

Results

The examined parameters were not changed by the perfusion fluid (2 ml) except for a transient increase in coronary perfusion pressure and for a small increase in left ventricular systolic pressure present only during the perfusion period (20 s)

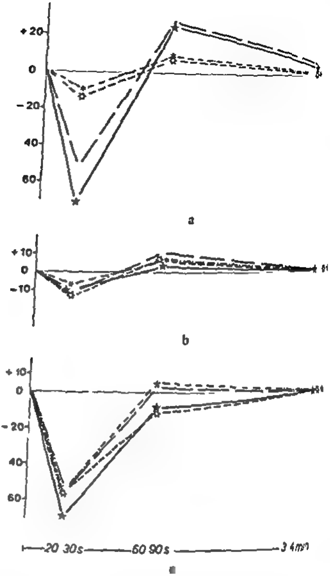

Fig 1 Changes in per cent (mean values) at 20 to 30 s at 60 to 90 s and at 3 to 4 min from start of injection a) Left ventricular systolic pressure b) Heart rate c) Coronary perfusion pressure d) First derivative of left ventricular pressure e) Shortening velocity of the contractile element extrapolated to zero load from developed pressure — Urografin 76 Iopamidol — — Glucose solution with same osmolality as Urografin - - Glucose solution with same osmolality as Iopamidol

volume of 2 ml (a) Urografin 76 % (Schering Milano Italy sodium and meglumine diatrizoate) 370 mg I/ml viscosity 8 6 cP osmolality 1 770 mol/kg H O (b) Iopamidol (FELDER et coll 1977) (Bracco Industria Chimica Milano Italy a non ionic water soluble contrast medium) 370 mg I/ml viscosity 8 6 cP osmolality 0 796 mol/kg H O (c) Glucose solution having the same osmolality as Urografin 76 % (d) glucose solution having the same osmolality as Iopamidol and (e) perfusion fluid

The solutions were neutralized at pH 7 4 with NaOH and injected in each heart at 37 C in randomized order the time of injection was 20 s and the injections were performed with an interval of 20 min

The same dose of the two contrast media was also administered in 3 hearts perfused with Propranolol (1 μg/ml) and in 3 with Cimetidine (1 μg/ml) The perfusion of these substances was continuous and the injections of contrast media were started 10 min after the onset of perfusion

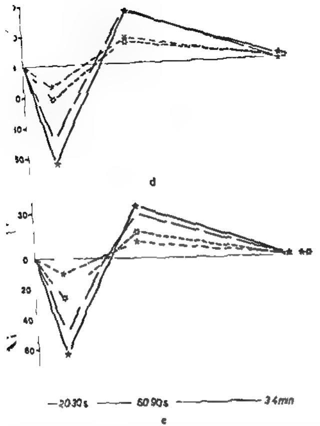

Fig. 1 (For legend see opposite page.)

Statistical analysis A paired Student's t test was done in order to compare the changes between basal values and the maximum effect observed in all parameters after each injection (Table 1) and a variance analysis was performed in order to evaluate the significance of the difference between the cardiovascular changes induced by Iopamidol Urografin and their iso osmolal glucose solutions

Three different analyses were performed between the two contrast media and between each contrast medium and its iso-osmolal glucose solution For each analysis a randomized block factorial design 2 × 2 was assumed the substances as first factor the base-effect association as second factor This analysis provided three *F* tests and because of the equality of the basal values only the interaction of the factors was considered (Table 2)

Results

The examined parameters were not changed by the perfusion fluid (2 ml) except for a transient increase in coronary perfusion pressure and for a small increase in left ventricular systolic pressure present only during the perfusion *period (20 s)*

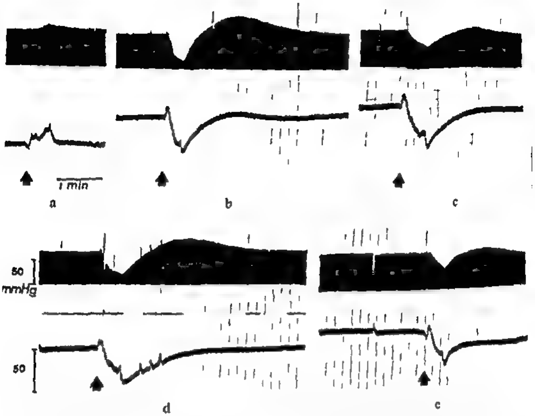

Fig 2 Example of the effects induced by the injection of the various substances a) Perfusion fluid b) Urografin 76 c) Iopamidol 370 d) Glucose solution with same osmolality as Urografin e) Glucose solution with same osmolality as Iopamidol Left ventricular systolic pressure (top) and coronary perfusion pressure (bottom) Arrow indicates start of injection

The effects observed with the various substances appear in Figs 1 and 2 The coronary perfusion pressure after an early transient increase due to the injection showed a marked decrease which reached a maximum at 20 to 30 s after the start of the injection Simultaneously the left ventricular systolic pressure decreased markedly both with Urografin and with its iso osmolal glucose solution, while it slightly decreased with Iopamidol and with the glucose solution having the same osmolality Small changes in heart rate but no changes in left ventricular diastolic pressure occurred in any of the experiments

A decrease in dP/dt in Vce max and in Vmax was also present which was much lower with the low osmolality substances (Iopamidol and its iso osmolal glucose solution Table 1) The coronary perfusion pressure tended to return to control levels whereas all the other parameters still increased with a maximum at 60 to 90 s

This increase was significantly higher with the higher osmolality substances (Urografin and its iso osmolal glucose solution Table 2) The basal levels were always reached within 3 to 4 min The inotropic stimulation induced by contrast media was unaffected in the hearts perfused with Propranolol or Cimetidine (Fig 3) The differences between the changes induced by the two contrast media were statistically

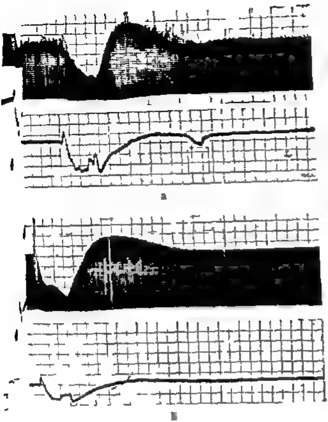

Fig 3 Changes induced by injection of Urografin 76 on left ventricular systolic pressure and coronary perfusion pressure a) Before and b) during perfusion with Cimetidine 1 µg/ml)

significant whereas the differences between the changes induced by a single contrast medium and the respective glucose solution were not statistically significant (F test Table 2)

Discussion

The results show that after the injection of contrast media or of hypertonic solutions the same changes in cardiac contractility were observed in isolated rabbit hearts as had been shown in dogs

Following a depression of left ventricular function supported by the decrease of contractile indices a significant enhancement of cardiac contractile force was observed HAJDU (1953) KOCK WESER (1963) BROWN et coll (1965) WILDENTHAL et coll (1969 a) and ROBERTS & HUGHES (1977) have found experimentally that changes in plasma or perfusing fluid osmolality may influence the contractility either increasing or decreasing it

KOCH WESER reported that increasing osmolality of the perfusate up to certain levels caused an increase of contractility in right atrial strips of kittens but a further increase in osmolality was associated with a decline of tension WILDENTHAL et coll (1969 b) reported similar results in papillary muscle from the right ventricle in the cat and ROBERTS & HUGHES in spontaneously beating rabbit atria HAJDU described an increase in tension following perfusion of hypertonic substances in a semi isometric frog ventricle preparation

NAYLER (1961) reported that the reduced amplitude of contractions occurring on perfusion of isolated ventricular muscle in Ringer s solution made hypertonic by the addition of sucrose was rapidly followed by states of tetanus and of contracture

In the present experiments only minimal changes in contractility occurred with the lower osmolality agents Iopamidol having half of the osmolality of Urografin produced a lower decrease and a lower increase in contractility than Urografin A similar result was obtained comparing the glucose solution iso osmolal with Iopamidol with the one having the same osmolality as Urografin

The differences between the changes induced by Iopamidol and by Urografin were statistically significant whereas the differences were not significant between a single contrast medium and the respective iso osmolal glucose solution

The results indicate that the observed changes in contractility are due to the hypertonicity of the substances employed even the changes in perfusion pressure seem to be caused by the hyperosmolality of the agents This effect suggests a reduction in coronary resistance and is in agreement with the increase of coronary blood flow observed in vivo by BASSAN et coll (1975) and WILLERSON et coll (1975) after to injection of hypertonic solutions Since the effect was similar for all the substances it cannot be directly influenced either by the iodine component of the contrast media or by Na^+ ions which are present only in the Urografin molecule

At present the mechanism involved in the enhancement in contractility observed is not clear Many hypotheses have been suggested such as (1) an increase in calcium concentration of the muscle fiber (KOCH WESER) (2) a release of catecholamines within a certain range of osmolality (WILDENTHAL et coll 1969 a) (3) a stimulation of H_2 histaminergic receptors which is known (BROADLEY 1975) to produce an intense inotropic effect on isolated rabbit heart Histamine is known to be released by chemical agents in contrast media (ROCKOFF et coll 1970 1971 LEITT et coll 1975)

In order to test the last two hypotheses the same dose of the two contrast media was administered in hearts perfused with Propranolol and with a classical H receptor antagonist Cimetidine but the inotropic stimulation was unaffected

Conclusion The observed changes in contractility following the injection of contrast media appear to be linked to hyperosmolality The mechanism of action is not completely clear However the increase in contractility is probably not due to catecholamines or histamine release future experiments will be performed in order to elucidate the role of calcium in causing this effect

SUMMARY

A low osmolality contrast medium (Iopamidol) caused less cardiac disturbance on isolated abbit heart than a high osmolality medium (Urografin) The same effects were induced by lucose solutions iso-osmolal with the two media After perfusion with Propranolol (1 µg/ il) and Cimetidine (1 µg/ml) the observed effect was unaltered

ZUSAMMENFASSUNG

Ein Kontrastmittel mit niedriger Osmolalitat (Iopamidol) verursachte geringere Verände ungen am isolierten Kaninchenherzen als das Mittel mit hoher Osmolalität (Urografin) Die gleichen Effekte wurden durch Glukoselosungen isoosmolal mit diesen beiden Mitteln hervorgerufen Nach Perfusion mit Propranolol (1 µg/ml) und Cimetidine (1 µg/ml) war der beobachtete Effekt unverandert

RÉSUMÉ

Un moyen de contraste à faible osmolalité (Iopamidol) a causé moins de trouble cardiaque sur le cœur isole de lapins qu un moyen de contraste à forte osmolalité (Urografin) Les memes effets ont été produits par des solutions glucosées iso-osmolaires avec ces deux moyens de contraste Après perfusion par Propranolol (1 µg/ml) et par Cimetidine (µ g/ml) les effets observés ont été inchangès

REFERENCES

BASSAN M GANZ W MARCUS A S and SWAN H J C The effect of intracoronary injection of contrast medium upon blood flow Circulation 51 (1975) 442

BROADLEY K J The role of H_1 and H_2 receptors in the coronary vascular response to histamine of isolated perfused hearts of guinea pigs and rabbits Brit J Pharmacol 54 (1975) 511

BROWN R RAHIMTOOLA S M DAVIS G D and SWAN H J C The effect of angiographic contrast medium on circulatory dynamic in man Circulation 31 (1965) 234

COLLA B BONGRANI S DEI CAS L e VISIOLI O La valutazione della contrattilità cardiaca mediante computer (In Italian) G ital Cardiol 4 (1974) 554

DI DONATO M BONGRANI S CUCCHINI F FERRARI R FAPPANI A e VISIOLI O Gli effetti dei mezzi di contrasto iodati sulla funzione contrattile del cuore Ricerca sperimentale nel cane (In Italian) G ital Cardiol 8 (1978) 283

FALLEN E L ELLIOT W C and GORLIN R Apparatus for study of ventricular function and metabolism in the isolated perfused rat heart J appl Physiol 22 (1967) 836

FELDER E PITRÉ D and TIRONE P Radiopaque contrast media Preclinical studies with a new non ionic contrast agent Il Farmaco 11 (1977) 835

HAJDU S Mechanism of staircase and contracture in ventricular muscle Amer J Physiol 174 (1953) 371

KOCK WESER J Influence of osmolality of perfusate on contractility of mammalian myocardium Amer J Physiol 204 (1963) 957

LEITE M P DE MORAES C R and GARCIA LEME J In vitro and in vivo release of histamine by contrast media in the rat Acta radiol Diagnosis 16 (1975) 172

NAYLER W G Influence of hypertonic solutions on ventricular contractile activity Amer J Physiol 201 (1961) 682

ROBERTS L A and HUGHES M J Chronotropic response of spontaneously beating rabbit atria to hyperosmotic media Amer J Physiol 233 (1977) 228

ROCKOFF S D KUHN C and CHRAPLYVY M Contrast media as histamine liberators II In vitro mast cell histamine release by methylglucamine salts Invest Radiol 6 (1971) 186

— BRASCH R KUHN C and CHRAPLYVY M Contrast media as histamine liberators I Mast cell histamine release in vitro by sodium salts of contrast media Invest Radiol 5 (1970) 503

WILDENTHAL K WIERZWIAK D S and MITCHELL J H (a) Acute effect of increased serum osmolality on left ventricular performance Amer J Physiol 216 (1969) 898

— SKELTON C L and COLEMAN H N (b) Cardiac muscle mechanism in hyperosmotic solutions Amer J Physiol 217 (1969) 302

WILLERSON J T WATSON J T HUTTON I FIXLER D E CURRY G E and TEMPLETON G H The influence of hypertonic mannitol on regional myocardial blood flow during acute and chronic myocardial ischemia in anesthetized and awake intact dogs J Clin Invest 55 (1975) 892

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ANGIOGRAPHY, ULTRASOUND AND FINE NEEDLE ASPIRATION BIOPSY IN THE EVALUATION OF GYNECOLOGIC TUMORS

S KARLSSON and P H PERSSON

Ovarian carcinoma is a common malignant disease affecting relatively young women The 5 year survival rate of patients with ovarian carcinoma is discouragingly low despite refined operative techniques and improved irradiation and chemotherapy It is essential to have a precise preoperative diagnosis if the survival rate is to be increased Therefore a combination of ultrasound angiography and fine needle aspiration biopsy was used in an attempt to increase the exactness of the preoperative diagnosis and the results are now reported

Material and Methods

During a 3 year period 63 women aged 29 to 76 without previous history of gynecologic tumors were referred to the Department of Gynecology and Obstetrics because of a palpable pelvic mass The presence of a tumor was confirmed by an ultrasound examination and angiography was then performed in all patients

All patients were examined with the compound B scan technique (Kretz Technic Combison II) with their urinary bladders filled Transducers of 1 2 25 and 4 MHz were used The tumors were evaluated *in respect of their* size shape nature (solid or cystic) and site (uterine or extrauterine left or right sided) Attempts to differentiate between malignant or benign tumors by means of ultrasound were not made

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Fine needle aspiration biopsy of the tumors guided by ultrasound was perform on 26 of the patients The cytologic examinations were done by a cytologist and c rent cytologic criteria on malignancy were used

Lumbar aortography was performed with a pigtail catheter with six side hol OD/ID 2 2/1 45 mm The curve of the catheter was placed at the level of the seco lumbar vertebra to demonstrate the origin of the ovarian arteries and give a gener view of the vascular supply of the tumors The contrast medium Isopaque Coron was injected at a rate of 20 ml/s to a total of 30 ml The films were exposed at a rate of 2 films/s for 3 s and then 1 film/s for 6 seconds If an ovarian artery on e side was wide enough, i e 1 to 1 5 mm in diameter a selective catheterization of the artery was attempted with the technique previously reported (KAHN & FRATES 1969 FRATES 1969 NORDMARK 1977) The catheter had OD/ID 2 2/1 45 mm with the tip tapered to the size of a guide wire of 0 635 mm (0 25 inch) in diameter The contrast medium was injected by hand using 4 to 7 ml depending on the size of the vessel The films were exposed at a rate of 1 film/s for 12 seconds

Bilateral selective internal iliac angiography was then performed one series with the ray direction 3° cranially and another with the ray directed 3° caudally to allow stereoscopy The catheters used had the same size as mentioned but without tapered tips The contrast medium was injected via a Y connection at a rate of 15 ml/s to a total of 20 ml The films were exposed at a rate of 2 films/s for 2 s 1 film/s for 4 s and then 1 film every other second for 8 seconds

Lumbar aortography and selective bilateral internal iliac angiography were per formed in all 63 patients Selective catheterization of the ovarian artery was at tempted late and in the present series only 4 selective ovarian angiographies a e in cluded The tumors were considered malignant when pathologic vessels were dem onstrated i e irregular vessels of different calibers not normally occurring at th sites of the ovaries

All patients were operated upon and the size, shape site and origin of the tumor were established and correlated to the preoperative examinations All operativ specimens were examined microscopically

Results

The postoperative diagnoses are given in Table 1 The average age of women wi malignant tumors was almost the same as for women with benign lesions 57 and years respectively

Fibromyomas (18 patients median age 55 years) Ultrasound suggested an enlarg ment of the uterus or a solid tumor in direct connection with the uterus in 15 of patients with myomas (Table 2) The correct size and shape were predicted in cases In 2 patients the origin of the solid tumors was not established and one stalk myoma was mistaken for a solid ovarian tumor

At angiography the diagnosis of fibromyoma was made in 17 of the 18 patie

a b

Fig 1 Bilateral internal iliac angiography a) Early b) late arterial phase Enlarged myomatous uterus Uterine arteries (↦) Intramural myomas (→)

Table 3 Fig 1) One patient had besides the diagnosed fibromyoma a lesion with pathologic vessels at the site of the left ovary which was suggestive of an ovarian carcinoma At operation this proved to be an old inflammatory lesion A large stalked myoma was erroneously considered to be an ovarian carcinoma

Fine needle aspiration biopsy was performed on 3 patients and no malignant cells were observed (Table 4)

Benign ovarian cysts (17 patients median age 55 years) By ultrasound 14 cases of simple cysts two endometroid and one dermoid cyst were correctly diagnosed regard

Table 1

Postoperative diagnoses and size of tumors

Final diagnosis	No of cases	Largest diameter of tumor		
		<5 cm	6–15 cm	16–30 cm
Fibromyomas	[illegible]	—	16	2
Benign ovarian cysts	17	6	8	3
Ovarian carcinomas	0	3	11	6
Tumors of possible malignancy	6	1	5	—
Sactosalpinx	2	1	1	—
Total	63	11	41	11

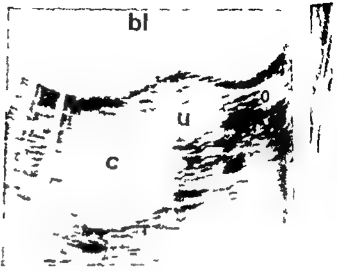

Fig 2 Ultrasound transversal At the top the extended urinary bladder (Bl) To the right of the uterus (U) a 4 cm simple cyst (C) On the left side a normal ovary (O)

ing their size and shape (Fig 2) Two cysts were considered to be solid tumors Th origin of two large cysts filling most of the abdomen was not possible to determine

Angiography determined correctly the origin of the cysts in all cases (Fig 3) Pathologic vessels were demonstrated in only one patient where the vascularity s gested malignancy in a small area at the site of the left ovary At operation this proved to be necrosis of fatty tissues (Table 3)

Fine needle aspiration biopsy was performed on 7 women (Table 4) The material obtained was not sufficient to allow a proper diagnosis in any of the cases but in 4 it was possible to assume that the lesion was benign

Ovarian carcinomas (20 patients median age 57 years) In 4 patients carcinomas were present in both ovaries

Table 2

Ultrasound reliability

Postoperative diagnoses	No of cases	Size and shape	Correct diagnoses regarding		
			uterine/ extra uterine	solid/ cystic	right / left sided
Fibromyomas	[illegible]	18	15	18	—
Benign ovarian cysts	17	17	17	15	15
Ovarian carcinomas	20	20	19	20	14
Tumors of possible malignancy	[illegible]	6	5	[illegible]	5
Sactosalpinx	2	2	2	2	2
Total	63	63	58	61	36

a b

ig 3 Benign simple cyst 6 cm in diameter at the site of the left ovary a) Early arterial phase Left uterine artery (←) and its ovarian branch (→) supplying the tumor b) Capillary phase Size and shape of the cyst visible due to accumulation of contrast medium in the wall of the cyst

Table 3

Angiographic reliability

Size (cm)	No of cases	Diagnosis	
		Correct	Erroneous
Fibromyomas			
<5	—	—	—
6–15	16	15	1
16–30	2	2	—
Total	[illegible]	17	1
Benign ovarian cysts			
<5	6	6	—
6–15	8	7	1
16–30	3	3	—
Total	17	16	1
Ovarian carcinomas			
<5	3	2	1
6–15	11	10	1
16–30	6	5	1
Total	0	17	3

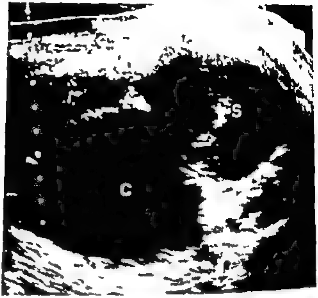

Fig. 4. Ultrasound transversal. Ovarian carcinoma on the right side. The tumor consists of a solid part (S) and a cystic part (C).

Ultrasound suggested the correct size, shape and nature in all patients but one where a solid ovarian tumor was erroneously considered to be a fibromyoma. The side of origin could be determined in 14 patients (Fig. 4). Carcinomas in ovaries of normal size were present in 2 women with bilateral carcinomas and these small tumors were not observed.

At angiography the origin of the tumors was correctly diagnosed in 19 cases. Three malignant tumors were erroneously considered to be benign since no pathologic vessels were demonstrated. In one woman the angiography was later repeated and this second time pathologic vessels were found (Table 3).

Fine needle aspiration biopsy was performed on 12 patients (Table 4). In 8 of these the correct diagnosis of ovarian carcinoma was reached; in 4 the diagnosis was either benign or the material obtained did not allow proper evaluation.

Tumors of potential malignancy (6 patients). Ultrasound demonstrated these tumors correctly concerning size, shape and nature in all women but one where a solid ovarian tumor was considered to be a fibromyoma.

Table 4

Results of fine needle aspiration biopsy in 22 cases

	No. of cases	Not conclusive	Conclusive
Fibromyomas	3	3	—
Benign ovarian cysts	7	3	4*
Ovarian carcinomas	12	4	8

* Benignancy established but not the exact type of tumor

ıngiography demonstrated pathologic vessels in 2 of the cases while the other 4 e considered to be benign

'ine needle aspiration biopsy was performed in 4 patients and malignant tumor s were found in 2 of them the same two women in whom angiography dem ıtrated pathologic vessels The other two specimens contained no tumor cells ıcating malignancy At microscopy no obviously malignant cells were found in 'se cases

Inflammatory lesions (2 patients) Ultrasound demonstrated a cystic tumor in 2 tıents with sactosalpınx

Angiography showed pathologic vessels at the site of the ovaries in these patients t because of a remarkably rich vascularity with accumulation of contrast medium t previously observed in carcinomas these lesions were correctly considered to be 'lammatory

Regarding all kinds of tumors taken together ultrasound could differentiate be ıeen extra or intrauterine tumors in 90 per cent of the cases Differentiation etween cystic and solid tumors was possible in a slightly higher percentage and etween right or left sided tumors in 80 per cent of the patients (Table 2)

Angiography could determine the origin of the tumors extra or intrauterine left r right sided in 95 per cent of the examinations A correct differentiation between ıalignant and benign tumors was obtained in 90 per cent if the two tumors with un ertain microscopic appearance in which angiography and fine needle aspiration ıopsy quoted malignancy are considered malignant and the other 4 benign Attempts o differentiate between cystic and solid tumors angiographically were not made In ' cases the tumors were erroneously considered malignant and in 3 benign

Fine needle aspiration biopsy was performed on 26 patients Malignancy was cor rectly diagnosed in about 60 per cent of the examinations including the 6 cases with tumors of potential malignancy

Two patients with bilateral ovarian carcinomas had at operation a macroscopic tumor on one side and on the other the ovary appeared to be normal but at micro-scopy carcinoma cells were found Neither tumor nor pathologic vessels were dem onstrated by ultrasound or angiography on the side of the macroscopically normal ovary

Discussion

For confirmation and evaluation of the findings of bimanual pelvic examination ultrasound has become a most valuable instrument Few other methods offer the same amount of information as safely quickly and reliably as ultrasonography The presence or absence of a tumor can be determined with high accuracy (SUNDÉN 1964 KOBAYASHI 1976 LEVI & DELVAL 1976) The correct description of a tumor with reference to its size shape site and nature (cystic or solid) can be achieved in about 80 per cent of the cases (MORLEY & BARNETT 1970 COCHRANE & THOMAS 1974)

Ultrasound per se cannot discriminate between malignant and benign processes (DONALD et coll 1958 THOMSON et coll 1966 KRATOCHWIL 1970) although the complexity of the ultrasound appearance correlates with the degree of malignancy The demonstration of multilocular cysts with solid papillary excrescences irregular or diffuse tumor capsules ascites etc, may indicate a malignant process However it should be emphasized that no specific proof of malignancy can be made by ultrasound at the present time Other limitations also exist it is often difficult to differentiate between various types of tumors although attempts have been made to evaluate the acoustic properties of different tissues (TACHEUCHI et coll 1975 LEVI & KEURALZ 1976) Even the origin of the tumor can sometimes be difficult to establish Solid tumors in connection with the uterus are most often fibromyomas A cystic or partly cystic tumor is probably of an ovarian origin

When large and non circumscribed tumors are present it may be difficult to determine the origin of the tumor With the proper appreciations of these limitations ultrasound is still very helpful in the preoperative evaluation of pelvic tumors but complementary methods for a correct final diagnosis are needed Fine needle aspiration biopsy may offer such a possibility (KJELLGREN et coll 1968 1971) The value of this method can be increased if guided by ultrasonography whereby the biopsy can be taken from desired parts of the tumors This method is however considerably limited by the fact that a negative biopsy does not exclude malignancy Another drawback might be the risk of cell dissemination when cysts are punctured

During the last two decades the accuracy of angiographic diagnosis has improved Improvement of the angiographic technique such as superselective catheterization pharmacoangiography and magnification has contributed to the progress Angiography still plays a subordinate part as a diagnostic method in gynecologic disorders Up to the present time gynecologic angiography has mostly been limited to carcinoma of the cervix and its recurrence to the diagnosis and the result of treatment of hydatidiform mole and the diagnosis of placenta praevia (BORELL et coll 1957 195 BREIT 1967 LATHROP & FRATES 1970) The standard angiographic technique used was aortography but the results were not too convincing (BORELL et coll 195 1955 FERNSTROM 1955 BREIT SMITH 1971) Bilateral selective angiography of the internal iliac arteries has improved the diagnostic possibilities (ALTEMUS 1968 1969 The value of selective catheterization of the ovarian artery in patients with pelvic tumor has also been pointed out (KAHN & FRATES FRATES LATHROP & FRATES)

In the present series it was possible to differentiate angiographically between malignant and benign lesions to a high accuracy if the tumors exceeded 4 to 5 cm diameter Two benign lesions were erroneously considered to be malignant due the presence of a concomitant inflammatory process In 20 patients with a microscopic diagnosis of ovarian carcinoma pathologic vessels could not be demonstrated in one of which had a severe atheromatosis the other 2 had normal vessels but the vascular supply of the tumors could not be demonstrated

The combination of ultrasound and angiography proved to be a most valuable

ocedure The evaluation of the size shape and nature of a tumor can easily be monstrated with ultrasound but seldom at angiography alone In patients with nple cysts or an enlargement of the uterus due to fibromyoma ultrasound alone in most cases sufficient to exclude malignancy Angiography not only proved to valuable in differentiating between malignant and benign tumors but was also ry reliable in discriminating between myomas and ovarian tumors However none the myomas in this series was smaller than 5 cm Fine needle aspiration biopsy oved to be of additional value in the diagnosis of malignancy but was less helpful *hen the tumor was benign*

In conclusion by the use of combined ultrasound angiography and fine needle piration biopsy the morphology and pathology of ovarian tumors can be deter ined in most cases and these tumors can be differentiated from other pelvic tumors

SUMMARY

The combination of angiography ultrasound and fine needle aspiration biopsy proved to be valuable in the preoperative evaluation of patients with a palpable mass With ultra ound the size shape and origin of tumors exceeding 4 to 5 cm in diameter were correctly diagnosed whereas angiography differentiated better between malignant and benign tumors

ZUSAMMENFASSUNG

Die Kombination von Angiographie Ultraschall und Fein Nadel Aspirations-Biopsie rwies sich als brau hbar bei der praoperativen Beurteilung von Patienten mit einem pal ablen Tumor Mit Ultraschall wurde der Sitz, die Form und der Ursprung des Tumors der 4 bis 5 cm in Diameter uberschreitet korrekt diagnostiziert wahrend durch Angio-graphie besser zwischen maligren und benignen Tumoren differenziert werden kann

RESUME

L association de l angiographie de l échotomographie et de la biopsie aspiration avec une aiguille fine s est montree utile pour l etude pre-opératoire de malades ayant une masse palpable Les ultra sons permettent de faire le diagnostic correct des dimensions de la forme et de l origine des tumeurs dont le diametre dépasse 4 à 5 cm alors que l angiographie a permis de mieux faire difference entre tumeurs malignes et tumeurs benignes

REFERENCES

ALTEMUS R Selective catheterization of the hypogastric arteries advantages and discus sion of technique Radiology 91 (1968) 484

— Differentiating uterine and extrauterine masses by bilateral selective hypogastric arterio-graphy Radiology 92 (1969) 1020

BORELL U FERNSTRÖM I and WESTMAN A The value of pelvic arteriography in the diag nosis of mole and chorionepitelioma Acta radiol 44 (1955) 378

— — LINDBLOM K and WESTMAN A The diagnostic value of arteriography of the [illegible] artery in gynecology and obstetrics Acta radiol 38 (1952) 247

BREIT A Angiographie der Uterustumoren und ihrer Rezidive Georg Thieme Ve[illegible] Stuttgart 1967

COCHRANE W J and THOMAS M A Ultrasound diagnosis of gynecological pelvis masses Radiology 110 (1974) 649

DONALD I MACVICAR J and BROWN T G Investigation of abdominal masses by pulsed ultrasound Lancet I (1958) 1188

FERNSTRÖM I Arteriography of the uterine artery Acta radiol (1955) Suppl No 122

FRATES R Selective angiography of the ovarian artery Radiology 92 (1969) 1014

KAHN P and FRATES R *The value of angiography of the small branches of the abd[illegible] aorta* Amer J Roentgenol 102 (1968) 407

KJELLGREN O DAHLGREN S och ÅNGSTRÖM T Finnålspunktion för cytologisk diagnostik av ovarialcancer (In Swedish) Läkartidningen 65 (1968) 1453

— ÅNGSTRÖM T BERGMAN F and WIKLUND D E Fine needle aspiration biopsy in diagnosis and classification of ovarian carcinoma Cancer 28 (1971) 967

KOBAYASHI M Use of diagnostic ultrasound in trophoblastic neoplasms and ovarian tumours Cancer 38 (1976) 441

KRATOCHWIL A Ultrasound diagnosis in pelvic malignancy Clin Obstet Gynec 14 (19[illegible]) 898

LATHROP J and FRATES R Selective ovarian angiography in trophoblastic disease Obstet Gynec 35 (1970) 844

LEVI S and DELVAL R Value of ultrasonic diagnosis of gynecological *tumours in 370* surgical cases Acta obstet gynec scand *55 (1976)* 261

— and KEURAEZ J An attempt to find a differential attenuation coefficient for ultrasonic diagnosis of pelvic tumours in vivo Proceedings of the First Meeting of the World Federation of Ultrasound in Medicine and Biology San Francisco 1976

MORLEY P and BARNETT E The use of ultrasound in the diagnosis *of* pelvic masses Brit J Radiol 43 (1970) 602

NORDMARK L Angiography of the testicular artery I Method of examination Acta radiol Diagnosis 18 (1977) 25

SMITH R S Pelvic arteriography in the differential diagnosis of pelvic mass Amer J Obstet Gynec 111 (1971) 952

SUNDÉN B On the diagnostic value of ultrasound in obstetrics and gynecology Acta obstet gynec scand (1964) Suppl No 6 p 164

TAKEUCHI H KOBAYASHI T KUSANO R and FURUYA H Ultrasound diagnosis of malignant ovarian tumours Proceedings of the Second European Congress Ultrasound in Medicine Munich 1975

THOMPSON H E HOLMES J H GOTTESFELD K E and TAYLOR E S Ultrasound as a diagnostic aid in diseases of the pelvis Amer J Obstet Gynec 98 (1966) 47

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RADIOLOGIC ASSESSMENT OF LARYNGEAL CARCINOMA

A clinico pathologic comparison based on whole organ serial sections

J OLOFSSON and H SÖKJER

For a correct classification of laryngeal carcinoma and to ensure the best planning of the treatment careful delineation of the tumour is essential The extent of the tumour is assessed by clinical endoscopic and radiographic examination (UICC 1973)

In a previous prospective series of laryngeal carcinoma (OLOFSSON & SÖKJER 1977) the radiographic information yielded by conventional films tomography and laryngography was compared with the findings at microlaryngoscopy It was concluded that the various types of examination are supplementary and that radiography is indispensible for the diagnosis and classification of laryngeal carcinoma Laryngography with a positive contrast medium was found to be superior to conventional films and tomography for detecting involvement of th anterior commissure and for detecting minor subglottic extension of the tumour to the inferior surfac of th vocal cord

Radiographic techniques applied in the examination of laryngeal carcinoma were discuss d in the previous report and it will suffice here to recall ■ few of the more salient points

Radiography was used by SCHEIER (1899 1901–1902) to demonstrate ossification of the laryngeal cartilages THOST (1913) applied radiographic techniques to laryngeal

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pathology. MAGUIRE (1966) introduced the high voltage technique with heavy filtration, which represented an improvement of the conventional examination. Tomography was used in the late thirties by GUNSETT (1937) and LEBORGNE (1940). Laryngography was introduced by IGLAUER in 1926 and the technique was further developed and its value confirmed by POWERS et coll. (1957, 1961, 1964). LANDMAN (1970) described the techniques and the applications of laryngography and cine-laryngography. Xeroradiography depicts the soft tissues of the larynx (DI GUGLIELMO & CHERUBINO 1975, SAMUEL 1975), but is inferior to laryngography in this respect (HEMMINGSSON & LÖFROTH 1976). The ossified parts of the laryngeal cartilages are visible and any tumour invasion can be detected although at the risk of erroneous evaluation of the images (NATHAN et coll. 1977).

The microlaryngoscopic technique evolved by KLEINSASSER (1968) has been widely adopted and has a variety of applications (KLEINSASSER 1976).

Whole organ serial sectioning enables a determination of the growth of a tumour within the larynx and of the different modes of cartilage invasion and tumour spread outside the larynx (OLOFSSON & VAN NOSTRAND 1973).

Few comparisons of radiographic and microscopic findings in laryngeal carcinoma have been reported. At the M. D. Andersson Hospital topographic comparisons have been performed between tomographic appearances and observations on whole organ laryngeal sections (FLETCHER et coll. 1954, MACCOMB & FLETCHER 1967).

HOLTZ et coll. (1963) compared the findings at laryngography with the gross pathologic findings in surgical specimens. In a similar retrospective analysis from the same centre (St. Louis) an assessment was made of the accuracy of laryngography for selecting patients with carcinoma of the supraglottic larynx and of the pharynx for conservative surgery (PEREZ et coll. 1968).

Comparison of radiographic and microscopic findings using whole organ serial sectioning was made by OLOFSSON et coll. (1973 a, 1975) and by HOMMERICH (1974).

The previous report (OLOFSSON & SÖKJER) has now been supplemented with a comparison between the preoperative clinical assessment on the basis of radiography and laryngoscopy, and the findings in laryngectomy specimens using the technique of whole organ sectioning.

Material and Methods

The present prospective series comprised all 33 patients who have been operated upon with partial or total laryngectomy for laryngeal carcinoma at this hospital over a 6 year period from February 1972 to January 1978.

Definitions. The regions of the larynx were defined in accordance with the criteria adopted by the Union Internationale Contre le Cancer (UICC 1973). The regions and the sites recognized are as follows:

Regions	Sites
(1) Supraglottis	
Epilarynx including marginal zone	Posterior surface of supra hyoid epiglottis including the tip
	Aryepiglottic fold
	Arytenoid
Supraglottis excluding epilarynx	Infra hyoid epiglottis
	Ventricular bands (false cords)
	Ventricular cavities
(2) Glottis	Vocal cord
	Anterior commissure
	Posterior commissure
(3) Subglottis	

The definitions agree with those formulated by the American Joint Committee (A J C 1972) and with the agreements reached at the Centennial Conference on Laryngeal Cancer held in Toronto (1974) the glottic region was defined as embracing the free margin and the horizontal surface of the vocal cords and the anterior and posterior commissures

All the carcinomas were classified according to the UICC and A J C definitions The tumour (T) classification may be summarized as follows

T1 Tumour limited to one region normal mobility
T2 Tumour involving more than one region no evidence of deep invasion
T3 Tumour limited to the larynx fixation for instance of the vocal cord
T4 Tumour extending into cartilage or beyond the larynx

These definitions apply to a clinical evaluation before treatment In the microscopic appraisal the conus elasticus was taken as the boundary between the glottic and subglottic regions a horizontal line through the lower lateral angle of the ventricles was taken as the border between the glottic and supraglottic regions (OLOFSSON & VAN NOSTRAND OLOFSSON et coll 1973 b Fig 1)

All but one of the 33 patients comprising the material were men The age range was from 43 to 76 years

For all the T1 and for most of the T2 tumours the primary form of treatment was irradiation surgery being reserved for *recurrent* or residual tumours Of the glottic tumours 2 were removed by partial vertical laryngectomy and one by an anterior commissure technique For one T1 supraglottic tumour (the female patient) preoperative irradiation was given before *supraglottic horizontal* laryngectomy

For most of the T3 and T4 tumours combined therapy was used preoperative

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Table 1

Type of tumour and treatment

	Primary surgery	Combined therapy	Recurrent tumour
Glottic carcinoma	4	9	10
Supraglottic carcinoma		7	3

Linear tomography was carried out with the patient in the supine position The exposure angle was 30 and the exposure time 0 32 s A multi section cassette and a tube potential of 70 to 90 kV were used Exposures were made during quiet inspiration and during phonation

Laryngography was performed by the method described by LANDMAN The contrast medium was aqueous Dionosil The exposure data were the same as for the conventional films and exposures were made during the same respiratory manoeuvres

Direct laryngoscopy was performed using the operating microscope as described by KLEINSASSER For surveying the valleculae piriform sinuses post-cricoid region and larynx an ordinary laryngoscope (Riecker) was used The subglottic region and the ventricles were also inspected with a 90 optical instrument

Whole organ serial sectioning The surgical specimen was cut open posteriorly and photographed and the extent of the tumour was recorded The specimen was then processed and serial sections were cut parallel to one of the three planes of the body chosen as offering the best possibility of determining the tumour growth and for comparison with the radiographic findings

Comparison The microscopic findings were used as a basis for ascertaining the merits of radiography and laryngoscopy in assessing laryngeal carcinoma All preoperative clinical data required for the comparison were recorded without knowledge of the microscopic findings

The following structures considered to be of importance for classification and prognosis were chosen namely the anterior commissure the subglottic region and the laryngeal ventricles the oropharynx (valleculae and base of tongue) and the laryngeal cartilages The implications of vocal cord fixation were appraised and a comparison was made between the classification based on the laryngoscopic findings alone and that based on the combination of laryngoscopy and radiography

Results

The results are presented in Tables 2 to 8 The values include definite and probable findings the latter are placed in parentheses

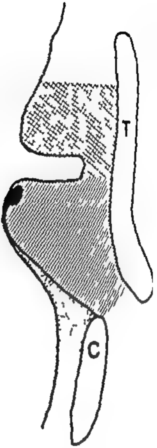


Fig 1 Laryngeal regions as defined microscopically Coronal section Maximum extent of a tumour confined to the glottic region (hatched area) Supraglottic extension (cross hatched area) Subglottic extension below the conus elasticus (stippled area) C = cricoid cartilage T = thyroid cartilage

irradiation (40–46 Gy) followed 4 weeks later by surgery In 4 patients the primary treatment was surgery (Table 1)

In 13 patients an operation was carried out following failure of irradiation within one year in 8 patients while in 5 patients the intervening period ranged from 14 months to 8 years

Examination procedure

Following a tentative diagnosis of laryngeal carcinoma based on mirror laryngoscopy, radiologic examinations were performed before the microlaryngoscopy and biopsy in order to avoid interfering oedema disturbing the evaluation of primary abnormalities

Conventional films A high voltage technique (135–150 kV) with 1 mm Cu filtration was employed Exposures were made during quiet inspiration phonation, inspiratory phonation and the Valsalva manoeuvre (expiration against closed lips and nose) One lateral view was exposed at 70 kV in order to examine the ossified parts of the laryngeal cartilages

Fig 2 (For legend se opposite page)

Table 2

Involvement of the anterior commissure

		Involvement demonstrated			Correct preoperative assessment (radiography micro-laryngoscopy)
		Conventional films	Laryngography	Micro-laryngoscopy	
Demonstrated in whole organ sections	19	6 (1)*	14 (3)*	16	18
Glottic carcinoma	17	6 (1)*	13 (3)*	15	17
Supraglottic carcinoma	2		1	1	1
Not demonstrated in whole organ sections	14		1**	2**	12
Glottic carcinoma	6		1**	2**	4
Supraglottic carcinoma	8				8

* Patients with probable involvement that are included in the preceding figure.
** One patient had involvement of the anterior commissure before irradiation, no residual tumour was present at this location at surgery.

Anterior commissure involvement (Table 2, Figs 3, 4, 5, 7, 8, 10, 11) can best be evaluated at laryngography, to some extent also on conventional films but not at a.p. tomography. The normal lateral laryngographic view exposed during inspiration usually depicts a slight dorsal bulging of the soft tissues within and below the anterior commissure. When the anterior commissure was involved by the tumour the bulge was more prominent and the mucosa usually irregular.

Anterior commissure involvement was microscopically evident in 19 laryngectomy specimens. It was found before operation in 18 patients, in 14 at radiography and in 16 at microlaryngoscopy. The involvement was demonstrated at laryngography in 14 patients, in 6 of these large tumours with anterior subglottic extension on conventional films. In 2 patients with tumour growth beneath an intact overlying mucosa, the anterior commissure involvement was assessed at laryngography but not at microlaryngoscopy.

Fig. 2. Large tumour of the left hemilarynx confined to the larynx, no cartilage invasion. (Primary surgery.) Arrows indicate tumour. a) Tomography, a.p. view. b) Laryngography, p.a. view. c) Laryngectomy specimen opened posteriorly. The exophytic tumour involves the left vocal cord with supraglottic and marked subglottic extension. d) Coronal section through the middle third of the vocal cords. The tumour is approaching but has not invaded the thyroid (T) or the cricoid (C) cartilage. THY = Thyroid gland.

Comment. The lower border of the tumour is clearly indicated in the films, but what appears to be the upper border is, in fact, normal tissue that has been displaced by the tumour. Although the tumour has produced distortion of the left piriform sinus, no evidence of mucosal involvement was found at microscopy.

Table 3

Subglottic involvement

		Involvement demonstrated				Correct preoperative assessment (radiography + microlaryngoscopy)
		Conventional films	Tomography	Laryngography	Microlaryngoscopy	
Demonstrated in whole organ sections	0	17	17	18	18 (1)	20
Glottic carcinoma	19	16	16	17	17	19
Supraglottic carcinoma	1	1	1	1	1 (1)	1
Not demonstrated in whole-organ sections	13	3 ( )	1 (1)	4 (2)		8
Glottic carcinoma	4	? (?)	1 (1)	3 (2)		0
Supraglottic carcinoma	9	1		1		8

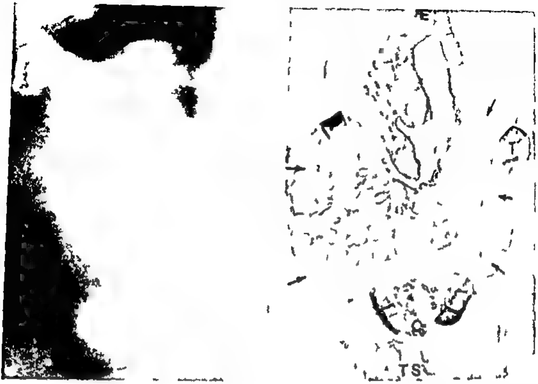
Patients with probable involvement that are included in the preceding figure
Tomography was not performed in one patient
Tomography was not performed in 5 patients

radiologic methods In one of these patients the subglottic extension occurred beneath an intact mucosa and at laryngoscopy subglottic oedema was suggested while the other patient had a subglottic extension of only a few millimeters

In 4 patients with recurrent glottic carcinoma and without microscopic indication of subglottic involvement the radiographic examinations suggested such an involvement In 2 of these the conventional films and laryngographic examinations indicated probable involvement as did tomography in the third patient Laryngography alone indicated subglottic involvement in the fourth patient in whom previous irradiation had resulted in subglottic asymmetry which accounts for the erroneous interpretation

Involvement of the laryngeal ventricles (Table 4 Figs 2 4 5 8) In assessment made on conventional films and tomograms the ventricles that were partly and symmetrically filled with air were considered to be unaffected by tumour Asymmetric partial filling was taken as evidence of invasion Bilateral absence of air filling was recorded as probable involvement (Table 4)

At microscopy evidence of ventricular involvement was found in 20 specimens In all cases it was demonstrated preoperatively in 18 ventricular involvement was observed at laryngoscopy and in the 2 others it was demonstrated by all the radiologic methods However these failed to disclose a small supraglottic extension



a b

Fig. 3. Large tumour with extensive destruction of cartilage and spread outside the larynx (Combined therapy.) a) Conventional film, lateral view. Destruction of the thyroid cartilage. b) Coronal section of the laryngectomy specimen close to the anterior commissure. Arrows indicate tumour. Only remnants of the thyroid alae (T) are visible. C = cricoid cartilage, E = epiglottis, TS = tracheostoma.

No involvement of the anterior commissure by tumour was found in 14 cases at microscopy. At microlaryngoscopy involvement was erroneously recorded in 2 cases. The tumour of one of these patients crossed the anterior commissure but it regressed from preoperative irradiation. The other patient had an exophytic tumour which, while advancing as far as the anterior commissure, did not actually involve it.

Subglottic involvement (Table 3, Figs 2–5, 7, 8, 10–13). Involvement of the subglottic region was found in 20 cases, all confirmed preoperatively. One large supraglottic tumour involved the subglottic region (Fig. 3) and this was indicated by all the methods of examination used. Subglottic carcinoma was correctly diagnosed preoperatively in all 19 cases of glottic carcinoma with subglottic extension. In 14 patients with marked subglottic extension all the examinations demonstrated involvement. In one patient with minor subglottic extension involvement was found at microlaryngoscopy and at laryngography (Figs 12, 13), and in another 2, both of them with a small subglottic extension below the anterior commissure at microlaryngoscopy alone. While microlaryngoscopy failed to show subglottic invasion in 2 patients, such involvement was demonstrated at all the

Table 3

Subglottic involvement

		Involvement demonstrated				Correct preoperative assessment (radiography + microlaryngoscopy)
		Conventional films	Tomography	Laryngography	Microlaryngoscopy	
Demonstrated in whole-organ sections	20	17	17	18	18 (1)	20
Glottic carcinoma	19	16	16	17	17	19
Supraglottic carcinoma	1	1	1	1	1 (1)	1
Not demonstrated in whole-organ sections	13	3 (?)	1 (1)	4 (2)		8
Glottic carcinoma	4	2 ( )	1 (1)	3 ( )		0
Supraglottic carcinoma	9	1		1		8

Patients with probable involvement that are included in the preceding figure
Tomography was not performed in one patient
Tomography was not performed in 5 patients

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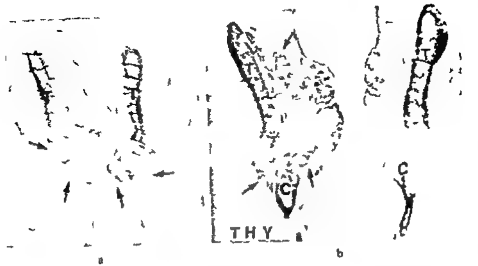
a

b

c

Fig 4 Tumour of the right hemilarynx with cartilage destruction spread outside the larynx (Primary surgery) Arrows indicate tumour a) Conventional film lateral view suggesting invasion of the anterior part of the thyroid cartilage b) Laryngography [illegible]a view Shallow piriform sinus c) Microlaryngoscopy Ulcerated tumour of the right vocal cord which was fixed Subglottic bulging and the right false cord felt hard on palpation with the suction tube



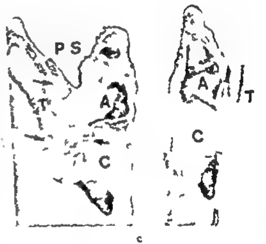


Fig 5 Same case as in Fig 4 Coronal sections of the laryngectomy specimen through the anterior commissure (a) through the middle third of the vocal cords (b) and through the arytenoid region (c) The tumour is growing for the most part submucosally and invading the thyroid (T) and cricoid (C) cartilages with spread out side the larynx through the thyroid cartilage anteriorly (a) and through the cri othyroid space laterally (b) where the tumour approaches the thyroid gland (THY) The tumour surrounds the right piriform sinus (PS) beneath the intact mucosa and is invading the cricothyroid joint (c) A arytenoid cartilage E epiglottis

Comment to Figs 4 and 5 The radiographic examination yielded valuable information regarding both the deep invasion and the vertical extent which was difficult to assess at laryngoscopy because of the mainly submucosal growth of this tumour

above the anterior commissure in one patient but this was demonstrated at laryngoscopy

Preoperative examination of the laryngeal ventricles yielded an erroneous evaluation in 6 patients with glottic carcinoma In one of them involvement of the ventricles was suggested at all examinations in one at laryngoscopy tomography and laryngography in one at all the radiologic examinations in one at both tomography and on conventional films in one each at tomography and on conventional films

a b

Fig. 6. Supraglottic tumour with oro- and hypopharyngeal spread. (Recurrent tumour after previous irradiation.) a) Laryngography, lateral view. Ulcerated tumour with large cavity through the epiglottis into the vallecula and base of the tongue (→). One aryepiglottic fold has been destroyed by the tumour (+→). Both arytenoid regions enlarged. b) Sagittal section of the laryngectomy specimen to the left of the midline. Arrows indicate tumour invading the base of the tongue above the hyoid bone (H), extending along the aryepiglottic fold and surrounding the left arytenoid cartilage (A). C = cricoid, T = thyroid cartilages.

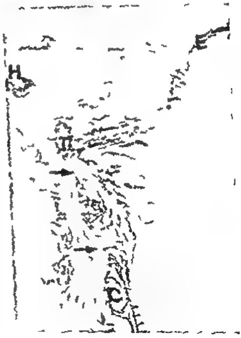
Comment: The tumour cavity at the base of the tongue was not observed at endoscopy. The information yielded by the radiologic examinations prompted a more extensive surgical procedure.

In one supraglottic carcinoma ventricular involvement was suggested at laryngoscopy, conventional film examination and laryngography, and in a second patient at laryngography alone. In neither case did microscopy provide confirmation.

Oropharyngeal extension (Table 5, Figs. 6, 9) was present in 5 of 10 supraglottic carcinomas. It was demonstrated in all cases on lateral conventional films and lateral laryngograms and in 3 patients at laryngoscopy. Of the 2 patients where the extension was found at radiography only, one had an extension to the vallecula beneath an intact mucosa and the other had a deep tumour ulceration into the base of the tongue (Fig. 6).

Cartilage invasion (Table 6, Figs. 3–5, 7, 9–11). On a lateral film the anterior part of an ossified thyroid cartilage forms a "figure of 8" and distortion of this is suggestive of invasion by tumour (BACLESSE 1960).

a b



c

Fig 7 Anterior glottic and subglottic carcinoma with invasion of the thyroid cartilage and spread outside the larynx through the cricothyroid membrane (Recurrent tumour after irradiation) a) Conventional film lateral view Absence of the upper posterior part of the figure of 8 configuration of the thyroid cartilage suggests destruction by the tumour (→) b) Laryngography lateral view Tumour at and below the anterior commissure (→) c) Sagittal section of the laryngectomy specimen close to the midline Carcinoma at and below the anterior commissure with invasion (upper arrow) of the thyroid cartilage (T) and spread through the cricothyroid membrane (lower arrow) C cricoid cartilage E = epiglottis H hyoid bone

Comment Cartilage destruction but not the spread *through* the cricothyroid membrane is suggested by the radiologic appearances

Table 4

Involvement of the ventricles

		Involvement demonstrated				Correct preoperative assessment (radiography microlaryngoscopy)
		Conventional films	Tomography	Laryngography	Microlaryngoscopy	
Demonstrated in						
whole organ sections	20	19 (3)*	16 (2)*	19 (1)*	18	20
Glottic carcinoma	15**	14 (3)*	13 (2)*	14 (1)*	13	15
Supraglottic carcinoma	5***	5	3	5	5	5
Not demonstrated in						
whole organ sections	13	5 (1)*	5 (1)*	5 (1)*	3	5
Glottic carcinoma	8***	4 (1)*	5 (1)*	3	2	2
Supraglottic carcinoma	5****	1		2 (1)*	1	3

* Patients with probable involvement that are included in the preceding figure
** Tomography was not performed in one patient
*** Tomography was not performed in 2 patients
**** Tomography was not performed in 3 patients

The thyroid and cricoid cartilages were invaded in 15 carcinomas The thyroid cartilage was invaded by 10 glottic and 3 supraglottic tumours In 8 cases such involvement was suggested by lateral low voltage conventional films In 2 of these patients with major destruction of the thyroid alae invasion was suggested by tomography

In one case of supraglottic carcinoma the left major cornu of the hyoid bone was destroyed by the tumour as was demonstrated in a lateral conventional film (Fig 9)

Tomography was indicative of probable invasion of the thyroid alae in 3 patients but in none of these was microscopic confirmation obtained In no case did findings of cartilage involvement on conventional films prove false

Fig 8 Exophytic glottic sub and supraglottic carcinoma involving both sides of the larynx (Primary surgery) Arrows indicate tumour a) Conventional film p a view b) Laryngography left lateral view c) Laryngectomy specimen opened posteriorly Exophytic tumour occupying left and right glottic and subglottic regions and the base of the epiglottis d) Coronal section of the laryngectomy specimen close to the anterior commissure Involvement of both vocal cords and extension subglottically (arrows) Right lower arrow vascular invasion outside the cricothyroid membrane

Comment The vertical extension of the tumour is demonstrated on the films but not the bilateral tumour involvement nor the spread outside the larynx

a

b

c

d

Fig. 8 (For legend see opposite page.)

a b

Fig 9 Supraglottic carcinoma with destruction of the hyoid bone (Combined therapy) a) Conventional film lateral view One major cornu of the hyoid bone has been destroyed b) Coronal section of the laryngectomy specimen at the middle part of the vocal cord The hyoid bone (H) on the left side is surrounded and invaded by tumour as is also the upper part of the left thyroid ala (T) C = cricoid cartilage E = epiglottis SG = submandibular gland THY = thyroid gland

Microscopic findings in vocal cord fixation (Table 7) Fixation of the vocal cord is an important clinical indication of deep tumour invasion It was recorded in 14 patients with glottic carcinomas In 8 it was the thyroid cartilage that was involved and in one of them also the cricoid cartilage this cartilage alone was invaded in another 2 cases The arytenoid cartilage alone was invaded in 2 cases Five glottic carcinomas with vocal cord fixation spread outside the laryngeal cartilages

In the case of 3 patients with supraglottic carcinoma the vocal cord was fixed 2 of them with thyroid cartilage invasion

Table 5

Oropharyngeal extension 10 supraglottic carcinomas

		Involvement demonstrated			Correct preoperative assessment (radiography + micro-laryngoscopy)
		Conventional films	Laryngography	Micro laryngoscopy	
Demonstrated in whole organ sections	5	5	5	3	5
Not demonstrated in whole organ sections	5				5

Table 6

Invasion of cartilage 15 carcinomas demonstrated in whole-organ sections

		Invasion demonstrated		Correct preoperative assessment
		Conventional films (lateral view 65 kV)	Tomography	
lottic carcinoma	12	6		6
Thyroid cartilage	10	6		6
Anteriorly	4	3		3
Alae	2			
Anteriorly + alae	4	3	1	3
Cricoid cartilage	2			
supraglottic carcinoma	3			2
Thyroid cartilage	3	[illegible]	1	2
Hyoid bone	1	1		1

Tomography was not performed in 2 patients

Comparison between clinical assessment and microscopic findings (Table 8) According to the UICC a tumour classification should be made b fore any kind of treatment is undertaken This was in fact performed although *it is not immediately* evident from Table 8 as for this comparison tumours recurring after irradiation were re-classified before surgery so as to enable meaningful comparison with the microscopic appearance In 5 of the 13 patients with recurrence this entailed a change in the original classification 3 T1 glottic carcinomas and one supraglottic were re-classified as T3 tumours One glottic subglottic T2 carcinoma was re classified as T1 the recurrence being localized to one vocal cord

No glottic tumour was classified as T4 solely on the microlaryngoscopic findings but radiographic evidence of cartilage destruction changed the classification to T4 in 6 patients

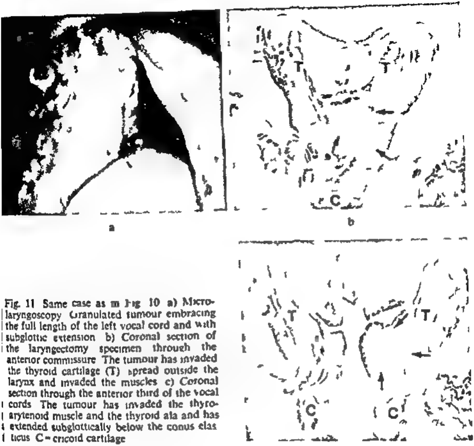
On the basis of laryngoscopy 8 glottic carcinomas were assigned as T2 tumours 2 of these had an anterior glottic subglottic extension and in both of them radiography correctly demonstrated anterior thyroid cartilage destruction changing the classification to T4 Fourteen glottic tumours were classified as T3 in 4 of these the radiographic appearances were correctly suggested to be caused by cartilage destruction In 6 glottic carcinomas all with vocal cord fixation no radiographic indication of cartilage destruction existed but microscopic examination showed that 2 had invaded the cricoid cartilage and 4 the thyroid cartilage Three of them also spread outside the larynx anteriorly through the cricothyroid membrane or laterally through the cricothyroid space

a

b

Fig 10 Glottic subglottic carcinoma with cartilage destruction and spread outside the larynx (Combined therapy) Arrows indicate tumour a) Conventional film lateral view suggesting invasion of the anterior part of the thyroid cartilage b) Tomography a p view Section through the posterior part of the thyroid alae Absence of the internal lamina of the thyroid ala (↔) not conclusive of tumour invasion c) Laryngography p a view The tumour is elevating but not obliterating the laryngeal ventricle

c



a b c

Fig. 11 Same case as in Fig 10 a) Microlaryngoscopy Granulated tumour embracing the full length of the left vocal cord and with subglottic extension b) Coronal section of the laryngectomy specimen through the anterior commissure The tumour has invaded the thyroid cartilage (T) spread outside the larynx and invaded the muscles c) Coronal section through the anterior third of the vocal cords The tumour has invaded the thyroarytenoid muscle and the thyroid ala and has extended subglottically below the conus elasticus C = cricoid cartilage

Comment to Figs 10 and 11 The surface extension and invasion of cartilage was assessed before surgery but not the spread outside the larynx

On the basis of the microscopic examination 9 supraglottic carcinomas were classified as T4 5 of these were correctly classified at laryngoscopy In a further 2 cases the classification was improved by radiography In one of these invasion of the thyroid cartilage was demonstrated at radiography and was microscopically confirmed and in the other submucosal extension to the vallecula was found

Discussion

The results confirmed the important role of radiography in the diagnosis of laryngeal carcinoma but it also uncovered shortcomings of current methods of examination

Involvement of the anterior commissure with the attendant serious risk of cartilage invasion (OLOFSSON et coll 1972 OLOFSSON & VAN NOSTRAND) was

a b

Fig. 12. Glottic carcinoma with minor subglottic extension amenable to partial surgery (Residual tumour after irradiation.) Arrows indicate tumour. a) Laryngography p.a. view before irradiation. b) Laryngography p.a. view 3 months after irradiation. Obliteration of the left ventricle.

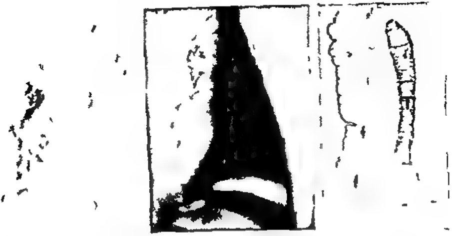
demonstrated before surgery in all but one of the 19 patients with such involvement. While involvement of the anterior commissure was not detected by microlaryngoscopy, it was indicated by laryngography in 2 of the patients with submucosal growth. It is important to identify the lower margin of a supraglottic carcinoma, especially when contemplating horizontal supraglottic laryngectomy (Fig. 14). The lateral laryngographic view is the most informative concerning the condition of the lower part of the epiglottis and the anterior commissure. These parts may be difficult to assess at endoscopy, especially in the case of an exophytic tumour.

Table 7

Microscopic findings in 14 glottic carcinomas with vocal cord fixation

Microscopy	No. of cases	Diagnosed preoperatively
Invasion of cartilage	12	4
Thyroid	8*	4
Cricoid	3*	
Arytenoid	4	
Spread outside the larynx	5	

* One tumour invaded both the thyroid and the cricoid cartilage



a b c

Fig 13 Same case as in Fig 12 a) Microlaryngoscopy Ulcerated tumour extending over the full length of the left vocal cord Hyperplasia but no atypia in the small lesion on the right vocal cord b) Microlaryngoscopy 3 months after irradiation Slight bulging beneath the intact mucosa anterior to the left vocal process Biopsy revealed residual carcinoma c) Hemilaryngectomy specimen Residual nests of tumour beneath an intact mucosa

In all 20 patients with subglottic extension it was correctly diagnosed Major subglottic extension blunting the subglottic angle was demonstrated by all the radiographic methods As would be expected laryngography yielded additional information on one carcinoma with a small subglottic extension to the inferior surface of the vocal cord (OLOFSSON & SOKJER) Radiography often provides a more exact de

Table 8

Comparison between clinical assessment and microscopy

	Tumour classification			
	T1	T2	T3	T4
Glottic carcinoma 23				
Microlaryngoscopy	1	8	14	
Microlaryngoscopy + radiography	1	6	10	6
Microscopy	1	6	4*	12
Supraglottic carcinoma 10				
Microlaryngoscopy	2	1	2	5
Microlaryngoscopy + radiography	1	1	1	7
Microscopy	1			9

Classified as T3 because the vocal cord was fixed before surgery

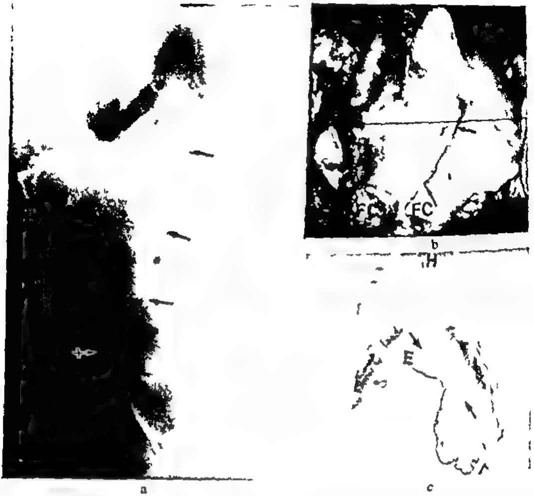


Fig 14 Epiglottic carcinoma amenable to supraglottic horizontal laryngectomy (Combined therapy). Arrows indicate tumour a) Laryngography lateral view The irregular tumour on the laryngeal surface of the epiglottis has not involved the anterior commissure (↔) b) Supraglottic horizontal laryngectomy specimen including the mucosa of the right piriform sinus No tumour visible after preoperative irradiation but only an excavation (arrows) Horizontal line = the level of the section in c c) Horizontal section indicated in b Residual tumour nests beneath the intact mucosa E = epiglottis FC = false vocal cord H = hyoid bone T = thyroid cartilage

lineation of the lower border of the tumour which may be growing beneath an intact mucosa (Figs 4 5) or may be exophytic and therefore difficult to assess even with 90° optical instruments It is thus clear that the laryngoscopic and radiographic examinations often complement one another

The erroneous radiographic suggestions of subglottic tumour involvement all occurred in patients with recurrent tumour after previous radiation therapy

Involvement of the ventricles was correctly diagnosed preoperatively in all 20 patients but by laryngoscopy alone in only 13 Also in these cases radiography provided supplementary information but suggestion of false involvement was common

An accurate diagnosis of the involvement of the laryngeal ventricles is crucial to the planning of horizontal supraglottic laryngectomy. It would appear that in doubtful cases this must be done during the operation.

A reliable assessment of any oropharyngeal extension is also important for correct treatment planning. The base of the tongue and valleculae should always be palpated, preferably at laryngoscopy with the patient relaxed under general anaesthesia, but even then such an extension may be undiagnosed. In 2 patients lateral conventional films and laryngography provided additional information (Fig. 6). In no case did a radiographic finding of oropharyngeal extension prove to be false.

When invasion of the laryngeal framework occurs it is usually the ossified parts that are involved (OGURA 1955, KIRCHNER 1969, OLOFSSON & VAN NOSTRAND). Because of the irregular ossification of the laryngeal cartilage, destruction is difficult to evaluate (WORNING 1934). However, in men of more than 50 years the anterior part of the thyroid cartilage is usually ossified (BACLESSE) and a lateral low voltage conventional film may be diagnostic. Cartilage involvement is most common at this site (OLOFSSON & VAN NOSTRAND). Moreover, in Sweden laryngeal carcinoma is 10 times more frequent in males than in females (The Swedish Cancer Registry 1973). Ulcerated supraglottic carcinomas may extend down across the anterior commissure and then a high risk of invasion of the anterior part of the thyroid cartilage exists (KIRCHNER & SOM 1971). This occurred in 2 such tumours in the present series.

No erroneous findings of cartilage involvement were recorded on the lateral low voltage conventional films depicting the anterior part of the thyroid cartilage. This suggests that in men above the age of 50 a finding of cartilage involvement is reliable, a conclusion that is consistent with the view expressed by BACLESSE, who also stated that in women the process of ossification occurs later and is more erratic. The only woman in the present series had a supraglottic carcinoma with no cartilage invasion. Obviously, no radiographic indication of involvement does not rule out the possibility of such invasion.

Fixation of the vocal cord constitutes an important clinical evidence of deep tumour invasion with a great risk of cartilage invasion and spread outside the larynx (OLOFSSON et coll. 1973 b); this is also exemplified in the present series. 10 of the 14 glottic carcinomas with vocal cord fixation were found to have invaded the thyroid or the cricoid cartilage and 5 spread outside the larynx. It has been stated that supraglottic tumours rarely invade the glottic region (BOCCA et coll. 1968), but in the *present series* 3 such tumours extended down into the vocal cord and caused fixation.

In the case of smaller tumours the complementary information yielded by the various diagnostic methods might be of critical importance. For example, for one of the supraglottic tumours the radiographic evidence of oropharyngeal extension prompted a change in the classification from T1 to T4. In major carcinomas the influence of the radiographic examination on the classification was most marked when

the films indicated cartilage destruction. The detailed mapping of the surface extension by radiography usually did not cause a change in the classification. The mucosal extension can be fairly accurately determined before operation, the horizontal extension by laryngoscopy and the vertical extension by radiography. However, the methods of examination used in the present series are insufficient for detection of deep tumour invasion and spread outside the larynx.

Conclusions

(1) In the classification of laryngeal carcinoma radiography should invariably be relied upon as a supplementary source of information.

(2) Laryngography is a more informative source of information concerning mucosal extension of the tumour than are the other radiographic methods used.

(3) Low voltage lateral films can provide additional information regarding destruction of anterior part of the thyroid cartilage.

(4) The examination methods used do not enable a correct assessment of deep tumour invasion to be made.

Acknowledgements

The skilful assistance in the photographic work provided by Thomas Johansson at the Department of Photography is gratefully acknowledged. Christer Bergman, Lena Hoglund and Lena Seiron prepared the whole organ sections. This investigation was supported by the Swedish Cancer Society and the Ollie & Elof Ericsson Research Fund.

SUMMARY

In 33 patients with laryngeal carcinoma operated upon with laryngectomy a comparison has been made of the findings yielded by radiography and microlaryngoscopy and a microscopic examination using whole organ serial sectioning. The radiographic examinations were conventional films, tomography and laryngography. Radiography supplemented the microlaryngoscopy with information of clinical importance. Surface extension of the tumour was fairly accurately assessed preoperatively, whereas deep infiltration was not. Major destruction of the anterior part of the thyroid cartilage was correctly diagnosed.

ZUSAMMENFASSUNG

Bei 33 Patienten mit einem Karzinom des Larynx, die mit Laryngektomie behandelt worden waren, wurden Vergleiche zwischen den Befunden bei Röntgenuntersuchung, Mikrolaryngoskopie und mikroskopischer Untersuchung von Gesamtorgan-Serien-Schnitte angestellt. Die röntgenologischen Untersuchungen bestanden aus konventionellen Röntgenuntersuchungen, Tomographie und Laryngographie. Die Röntgenuntersuchung ergänzte die Mikrolaryngoskopie mit Information von klinischem Wert. Der Oberflächenumfang des Tumors wurde relativ gut präoperativ festgestellt, während die Tiefeninfiltration nicht feststellbar war. Wesentliche Destruktionen des vorderen Teiles des Thyreoidea-Knorpels wurden korrekt festgestellt.

RESUMÉ

Sur 33 malades atteints de carcinome du larynx et operés par laryngectomie les auteurs nt compare les resultats de la radiographie de la microlaryngoscopie et de l examen microscopique utilisant les coupes seriées de l organe entier Les examens radiographiques nt ete les radiographies simples la tomographie et la laryngographie La radiographie a ompleté la microlaryngoscopie en fournissant des renseignements d intéret clinique L ex nsion en surface de la tumeur a été assez exactement determinee avant l operation alors que l infiltration en profondeur ne l a pas eté Les destructions importantes de la partie intérieure du cartilage thyroide ont été diagnostiquées correctement

REFERENCES

A.J C (American Joint Committee for Cancer Staging and End Results Reporting) Clinical staging system for carcinoma of the larynx Chicago 1972

BACLESSE F Tumeurs malignes du pharynx et du larynx Étude anatomo-topographique et radiographique Deuxième édition pp 190 664 Masson & Cie Paris 1960

BOCCA E PIGNATARO O and MOSCIARO O Supraglottic surgery of the larynx Ann Otol 77 (1968) 1005

FLETCHER C H OLD J W and LOQUVAM G S A topographic approach to the roentgenologic and pathologic examination of the laryngopharyngeal tumors Radiology 63 (1954) 361

DI GUGLIELMO L e CHERUBINO M Laringe *In* La xeroradiografia in otorinolaringoiatria 3? Raduno gruppo alta Italia (Pavia 29 novembre 1975) p 23 (In Italian) Edited by L. Di Guglielmo and M Cherubino Società italiana di otorinolaringologia e patologia cervico facciale Pavia 1975

GUNSETT A Über die Anwendungsmoglichkeit der Planigraphie bei Erkrankungen des Kehlkopfinneren insbesondere beim Karzinom des Endolarynx Fortschr Rontgenstr 56 (1937) 705

HEMMINGSSON A and LÖFROTH P O Xeroradiography and conventional radiography in examination of the larynx Acta radiol Diagnosis 17 (1976) 723

HOLTZ S POWERS W E MCGAVRAN M H and OGURA J Contrast examination of the larynx and pharynx Glottic infraglottic and transglottic tumors Amer J Roentgenol 89 (1963) 10

HOMMERICH K W Rontgenbefunde und mikroskopis hes Wachstum von malignen Larynxtumoren Laryng Rhinol 53 (1974) 845

IGLAUER S Use of injected iodized oil in roentgen ray diagnosis of laryngeal tracheal and bronchopulmonary conditions J Amer med Ass 86 (1926) 1879

KIRCHNER J A One hundred laryngeal cancers studied by serial section Ann Otol 78 (1969) 689

— and SOM M L Clinical and histological observations on supraglottic cancer Ann Otol 80 (1971) 638

KLEINSASSER O Mikrolaryngoskopie und endolaryngeale Mikrochirurgie Technik und typische Befunde F K Schattauer Verlag, Stuttgart New York 1968

— Mikrolaryngoskopie und endolaryngeale Mikrochirurgie Technik und typische Befunde Zweite Auflage F K Schattauer Verlag Stuttgart New York 1976

LANDMAN G H M Laryngography and cinelaryngography Excerpta Medica Foundation Amsterdam 1970

LEBORGNE F Tomographic study of cancer of the larynx Amer J Roentgenol 43 (1940) 493

MACCOMB W S and FLETCHER G H Cancer of the head and neck Williams & Wilkins Co Baltimore 1967

MAGUIRE G H The larynx Simplified radiological examination using heavy filtration and high voltage Radiology 87 (1966) 102

NATHAN M D SAGEL S S GALL A M GRIFFITH R C and OGURA J H Diagnostic accuracy of xeroradiographic assessment of extent of carcinoma of the larynx Trans Amer Acad Ophtalmol Otolaryngol 84 (1977) 609

National Board of Health and Welfare The Cancer Registry Cancer incidence in Sweden 1972 Stockholm 1973

OGURA J H Surgical pathology of cancer of the larynx Laryngoscope 65 (1955) 867

OLOFSSON J and VAN NOSTRAND A W P Growth and spread of laryngeal and hypopharyngeal carcinoma with reflections on the effect of preoperative irradiation 139 cases studied by whole organ serial sectioning Acta oto laryng (1973) Suppl No 308

— and SÖKJER H Radiology and laryngoscopy for the diagnosis of laryngeal carcinoma Acta radiol Diagnosis 18 (1977) 449

— RENOUF J H P and VAN NOSTRAND A W P (a) Laryngeal carcinoma Correlation of roentgenography and histopathology A study based on whole organ serially sectioned laryngeal carcinoma specimens Amer J Roentgenol 117 (1973) 526

— LORD I J and VAN NOSTRAND A W P (b) Vocal cord fixation in laryngeal carcinoma Acta oto laryng 75 (1973) 496

— WILLIAMS G T RIDER W D and BRYCE D P Anterior commissure carcinoma Primary treatment with radiotherapy in 57 patients Arch Otolaryng 95 (1972) 230

— FREELAND A P SÖKJER H RENOUF J H P VAN NOSTRAND A W P and GRÖNSTEN O Radiologic pathologic correlations in laryngeal carcinoma Canad J Otolaryng 4 (1975) 86

PEREZ C A OGURA J H HOLTZ S PALMER L A BARNHILL F H and POWERS W E Laryngography in the selection of patients for conservation surgery in cancer of the supraglottic larynx and pharynx Amer J Roentgenol 103 (1968) 746

POWERS W E MCGEE H H and SEAMAN W B Contrast examination of the larynx and pharynx Radiology 68 (1957) 169

— HOLTZ S and OGURA J Contrast examination of the larynx and pharynx Inspiratory phonation Amer J Roentgenol 92 (1964) 40

— — OGURA J ELLIS B L and MCGAVRAN M H Contrast examination of larynx and pharynx Accuracy and value in diagnosis Amer J Roentgenol 86 (1961) 651

SAMUEL E Xerography or conventional radiography for laryngeal examination? Canad J Otolaryng 4 (1975) 59

SCHEIER M Weitere Mitteilungen über die Anwendung der Rontgenstrahlen in der Rhino- und Laryngologie Fortschr Rontgenstr 1 (1899) 59

— Ueber die Ossification des Kehlkopfs Arch mikr Anat 59 (1901–1902) 220

THOST A Der normale und kranke Kehlkopf des Lebenden im Rontgenbild (Archiv und Atlas der normalen und pathologischen Anatomie in typischen Rontgenbildern) Fortschr Rontgenstr (1913) Ergänzungsband 31

WORNING B Roentgen examination of laryngeal and hypopharyngeal tumors Acta radiol 15 (1934) 8

U I C C (Union Internationale Contre le Cancer) TNM classification of malignant tumours (Larynx Classified 1972) Geneva 1973

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INFLUENCE OF MICROSCOPIC MOTTLE ON THE DEFINITION OF SMALL IMAGE DETAILS

K. SELIN and S. REICHMANN

In an excellent monograph ROSE (1973) stressed that the resolution of an imaging system in certain cases depends on the limitations imposed by a finite number of photons rather than on the less fundamental limitations imposed by the finite geometric response of the system. ROSE was mainly concerned with conventional TV systems. However, accumulating evidence appears to indicate that in clinical radiography the ultimate limit for recording small details of low contrast may be set by the background noise caused by the finite number of roentgen photons necessary for a proper exposure of a given film or screen-film combination (STERNGLASS et coll. 1975). When the speed of a screen-film system is increased, fewer roentgen photons usually contribute to the image and, at least for a high speed system, it might well be questioned whether the number of image forming photons is so low as to yield a noise-limiting resolution as described by ROSE. Certain observations indicate that this may actually be the case (REICHMANN et coll. 1978, HÅRDSTEDT 1978). Thus the depiction resulting from a high speed screen combined with a film of low sensitivity may be just as good as that obtained with a slower screen and a high speed film especially chosen to make the two systems have the same sensitivity, despite the fact that the faster screen produces a more unsharp image as measured by the modulation transfer function (MTF). In this case noise seemed to be the limiting factor

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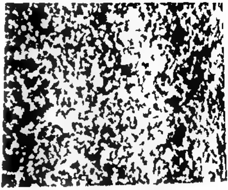

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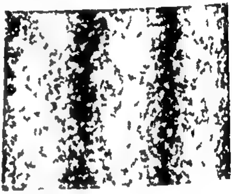

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Fig. 1. Images obtained after contact printing and magnification of films of a grid (44 lead bars/cm). a) Non screen industrial film. b) High speed screen (Agfa Gevaert MR 600) Curix RP 1 film. c) High definition screen (Kodak X omatic Fine) Curix film. (a) represents an almost ideal depiction of the lead bars (dark bands). In (b) an extreme fragmentation of the dark bands while in (c) these bands are well defined. (b) and (c) are referred to as type I and type II definition, respectively.

rather than MTF, even for imaging of such small details as are usually considered to be sharpness dependent. Part of this noise appears directly in the films as density fluctuations, but density variations may also appear that are so small as to escape detection by the unaided eye.

A technique for evaluation of this microscopic noise has been described previously (SELIN & REICHMANN 1979). A secondary ray grid (44 lead bars/cm) was exposed, the resulting image being copied and magnified ×32. In this magnified image the lead bars were represented by dark parallel bands. In an ideal depiction these zones would be sharply depicted (Fig. 1 a). Any deviation from this ideal image will in the following be called lack of definition. Two different appearances with regard to such lack of definition were suggested. One implied dark bands having a wavy outline and a more or less obvious fragmentation (Fig. 1 b), the other a homogeneously fading blackening towards the bright zones in the image (Fig. 1 c). In the following these two categories will be referred to as type I and type II, respectively. Apparently noise has a greater influence on definition in type I than in type II. Consequently it might be expected that type I would be encountered above all with radiation obtained at high kV recorded by high speed screen film combinations. If so, it should also be expected that the use of a low speed film would imply a drift towards type II definition, even if high speed screens were used. The present investigation was designed to confirm or reject these assumptions.

Table 1

[illegible]fame radiation doses required to give a film density of 0 9 to 1 0 for the screens tube potentials and [illegible]ded filtrations used The screens are in order of decreasing sensitivity (at 90 kV) A relative dose of [illegible] equals par speed (≃1 mR=0 26 μC/kg) Curix RP 1 film was used with the exceptions mentioned

[illegible]reen	Phosphor	Relative dose			
		45 kV 2 mm Al	90 kV 2 mm Cu	170 kV 2 mm Cu	0 5 mm Pb
[illegible]fa-Gevaert MR 600	LOB	72	19	18	
[illegible]iemens Titan	LOB	61	20	17	
[illegible]M Alfa 8 (green sensitized film)	GOS	13	24	18	
Philips Massiot Azuray II	BFC	11	25	18	
Kodak Lanex (green sensitized film)	GLOS	17	27	24	
Agfa Gevaert MR 400	LOB	83	[illegible]8	22	
Ilford rare earth (conventional film with speed half that of Curix)	LOB	16	38	33	
Kyokko LH II	CT	16	39	28	
Philips-Massiot Azuray III	BFC	14	39	32	
3M Alfa-4 (green sensitized film)	GOS	26	50	45	
Agfa Gevaert MR 400	LOB	16	50	37	
Kodak X-omatic Regular	BSS	46	61	50	
Siemens Safir	CT	[illegible]6	10	52	
Kyokko LT II	CT	25	11	54	
Agfa Gevaert MR 50	LOB	57	[illegible]	13	
Siemens Rubin	CT	53	23	14	
Siemens Rubin Super	CT	136	47	33	
Kodak X omatic Fine	BLS	133	56	39	

LOB – lanthanum oxybromide GOS gadolinium oxysulphide BFC – bariumfluorochloride GLOS gadolinium lanthanum oxysulphide CT calcium tungstate BSS – barium strontium sulphate BLS barium lead sulphate

Experiments

The technique was based on after treatment of films depicting an ordinary secondary ray grid (44 lead bars/cm ratio 1 10) This after treatment consisted in contact copying the double-emulsioned original film onto a single-emulsioned fine grain film (Kodalith Ortho Type 3) In this copying most of the granularity of the original film is lost the mottle still being preserved (SELIN & REICHMANN 1979) The elimination of the granularity makes evaluation of the mottle considerably easier The contact copy was magnified 32 by photomicrography The exposure arrangement including tube grid cassette and devices for measurement of tube potential and (relative) incident radiation dose appears in Fig 2 p 554 in SELIN & REICHMANN (1979)

A number of screens with different phosphors were tested at various tube potentials and added filtrations (Table 1) Green sensitized films were used for the green

Table 2

Relative doses (comparable to the values in Table 1) required for a selection of screens combined with Medichrome film developed at 35.5°C and 38.5°C. The higher temperature increases the film speed by a factor 2.5. Tube potential 90 kV, added filtration 2 mm Cu. (Same abbreviations as in Table 1)

Screen	Phosphor	Development (°C)	Relative dose
Philips Massiot Azuray II	BFC	35.5	6.7
		38.5	2.9
Agfa Gevaert MR 400	LOB	35.5	7.8
		38.5	2.9
Philips Massiot Azuray III	BFC	35.5	12
		38.5	4.4
Kyokko LH II	CT	35.5	13
		38.5	4.4
Kodak X-omatic Regular	BSS	35.5	20
		38.5	8.8
Agfa Gevaert MR 50	LOB	35.5	58
		38.5	22
Kodak X-omatic Fine	BLS	35.5	189
		38.5	82

emitting screens (Lanex, Alfa 4 and Alfa 8), and for the Ilford rare earth screen a film having about half the speed of that of Curix was used, as recommended by the manufacturer. The films were exposed to yield an average density in the range 0.9 to 1.0. Some screens (Table 2) were also tested at different dose levels for a fixed tube potential (90 kV). In order to minimize the influence of the film, the Medichrome film was used, the speed of which may easily be changed by varying the development, its excellent recording properties still being retained (SELIN & REICHMANN 1977, REICHMANN et coll.).

Even if the disturbing influence of the granularity of the original film was diminished by the copying, it was considered of interest to find out if any specific background in the radiographic film itself existed. Thus the Curix and Medichrome films were exposed by diffuse screen light from two X-omatic Regular screens situated in a cassette 3 cm from each side of the films. The films were then treated like the grid films.

Finally an experiment was performed to find out if the microscopic mottle in the magnified grid images could be reproduced to any significant degree, so that repeated exposures would lead to more or less identical distributions of density fluctuations. If so, the mottle must to a high extent depend on the crystal structure of the screen. Thus several grid images of the same area of a pair of screens were made. The magni-

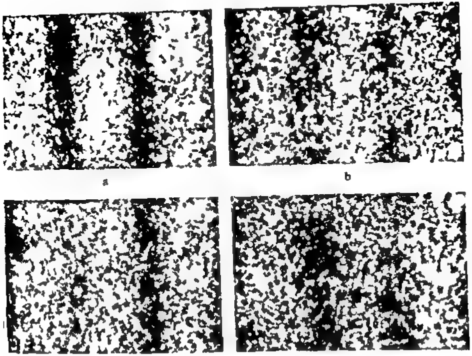


Fig 2 Grid images from lanthanum oxybromide screens Tube potential 90 kV a) Agfa Gevaert MR 50 Curix film b) MR 400 (7 times faster than MR 50) Curix film c) MR 400 Medichrome film developed at 35 5 C d) MR 400 Medichrome film developed at 38 5 C yielding an increase in film speed by a factor 2 5 as compared to (c) Increased screen sensitivity (same phosphor) implies a shift from type II to type I definition cf (a) and (b) Even for a given screen film combination a loss of definition occurs if the sensitivity of the system is increased cf (c) and (d)

fied images were superimposed and rotated in search of moire patterns which would indicate similarity of the mottles Different types of screens were tested in this way

Results

Regardless of tube potential and screen phosphor increasing sensitivity implied a shift from type II to type I definition (Fig 2 a b) At the same time the general contrast of the lead bar images decreased with increasing speed Since contrast was not controlled specifically at the development this factor was not analysed systematically However when a given pair of screens was combined with differently developed Medichrome films yielding a change in screen film speed (by a factor 2 5) an increasing loss of definition (type I) was observed in combination with decreasing exposure (Fig 2 c d) Increasing tube potential induced a shift towards type I definition regardless of screen sensitivity (Fig 3) For the 90 kV exposure type I defini

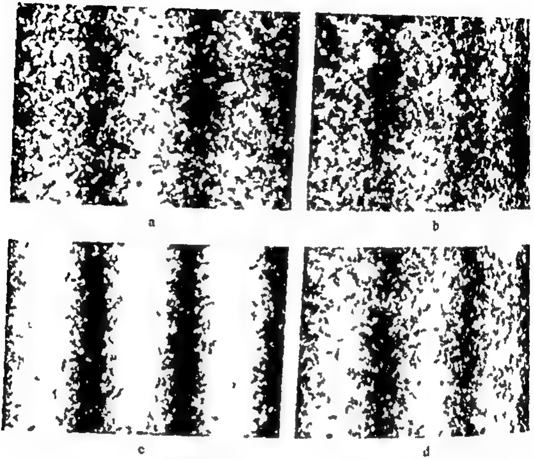


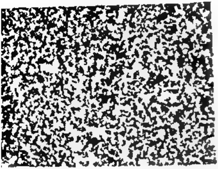
Fig 3 Influence of tube potential on the definition of grid images from different screen phosphors a) and b) Barium fluorochloride screens (Philips Massiot Azuray III) exposed at 45 kV and 140 kV respectively c) and d) Lanthanum oxybromide screens (Agfa Gevaert MR 50) 45 kV and 140 kV respectively The speed of Azuray is 4 times that of MR 50 Increasing tube potential induces a shift towards type I definition regardless of screen sensitivity If tube potential is kept constant increased screen sensitivity implies loss of definition

tion began to be of significance at par speed, gaining further importance for systems of higher sensitivity

The photographic emulsion itself displayed a certain mottle even after the photographic process used (Fig 4) This background was less disturbing in Medichrome film In neither of the films was it considered to be of great importance The crystal structure of the intensifying screens tested as to reproducibility of the mottle did not appear to have any significant influence Thus apart from the film mottle the mottle recorded displayed the properties of an unbiased quantum mottle

Discussion

Traditionally two aspects of image quality impairment have been recognized in diagnostic radiography viz unsharpness and mottle (Rossmann 1969) Unsharpness limitation has been considered above all for objects of high contrast and small extent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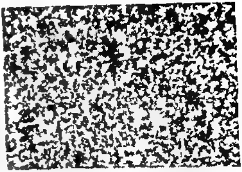
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Fig 4 The background mottle in a) Curix RP 1 and b) Medichrome The two films were exposed to diffuse screen light and then treated like the grid films The mottle is more prominent in (a) as compared to (b) but in neither of the two films it appeared to be significant

in the film plane A pure mottle limitation has been expected mainly for larger objects of low contrast Surprisingly little effort has been devoted to establishing the interaction between these two types of limitations As a matter of fact the crucial type of image detail in clinical radiography is neither of the two ones mentioned but is represented by small details of low contrast since decreasing object dimensions and decreasing absorption differences generally go together

A special case of interaction between unsharpness and noise limitation was analysed insofar as a high contrast object of small dimensions has been recorded by a series of screen film combinations yielding different degrees of unsharpness and mottle According to the predominant opinion on radiographic imaging increasing screen film sensitivity in this case would imply blurring of contours and lowering of contrast the contours still being straight although increasingly unsharp (type II definition) However decreasing exposure gives rise to an increasing quantum mottle The visual impression gained is that in high speed radiography the quality of the grid image is *mottle* limited (type I) besides the unsharpness limitation known from previous investigations The mottle in question is mainly microscopic its influence on the quality *of the unmagnified* original film can hardly be expected to appear like the mottle limitation introduced by a coarser directly visible mottle when large object details of low contrast are inspected Instead the mottle should affect sharpness and resolution in the same way as has been considered for other imaging systems by Rose

The object exposed gives rise to a square wave spatial frequency of about 4 lines/mm of extreme contrast In the 90 kV *recordings* of the grid the type I definition appeared to be of significance at par speed of the screen film system gaining in importance when still greater sensitivities *were used* This means that for the spatial frequency used par speed or high speed radiography will always be limited to a significant degree by microscopic *mottle rather than* by unsharpness Image details of biologic structures never give rise to the same contrast as details of metal grids

with equal spatial frequencies. It should be expected (ROSE) that decreasing contrast would make type I definition increasingly important as compared with type II definition. Thus for biologic objects type I definition may be operating even at lower sensitivity than par speed or lower spatial frequencies than 4 lines/mm or lower tube potential than 90 kV.

Basically type I definition appears in high speed systems where the MTF is also comparatively unfavourable. It might be asked whether this type of definition is just a reflection of the MTF so that evaluation of the MTF will, indirectly, give information about microscopic mottle as well. The inter-relationship between the factors determining type of definition may be considered as follows.

Regardless of screen speed the surface crystals of the fluorescent layer will always have the capacity to give rise to an image of low unsharpness, provided the protective layer is constant. If a considerable portion of the total light emission from the screen derives from this surface layer, then the image will be of low unsharpness. Let it be assumed that the surface crystal layer, having the potential to create a sharp image, has a constant depth, regardless of the total thickness of the fluorescent layer of the screen. The part of the fluorescent coating situated beyond the surface crystal layer may be called the background crystal layer. Thus it is implied that signals of high spatial frequency arising from the background layer will be so much diffused by their passage through the surface layer as to become negligible.

The MTF measured from the screen as a whole will be a function resulting from the interaction of the MTF of the surface and the background layers, respectively. This interaction will in turn be determined not only by the geometric spread of light from the two layers, but also by the relative luminosities of the light outputs from these layers. A thick screen coating will make the background crystal light emission predominate over that of the surface crystals. The sharp image created by the surface crystals will then be recorded with low contrast. On the other hand, in a screen with a thin coating the diffuse light from the background will be of minor importance so that the surface layer will give a sharp image of high contrast. The latter screen is generally apt to have a lower speed than the former. Thus, if both screens are used in conjunction with constant film sensitivity, high sharpness and heavy exposure will go together. This means different noise conditions in the whole roentgen relief absorbed by the screens. However, the point is that the noise of the roentgen relief recorded by the surface crystal layer will change to an even greater degree, as may be illustrated by the following hypothetical example.

At 90 kV the exposure required by the slowest lanthanum oxybromide screen (Agfa Gevaert MR 50) was about 10 times greater than that required by the fastest screen of the same type (Agfa Gevaert MR 600). Let it be assumed that the contribution from the surface crystal layer of the MR 50 screen amounts to 1/4 of the total light output, the corresponding figure for the fast screen being 1/16. The microscopic mottle which derives from the surface layer alone and severely disintegrates the grid image when the faster screen is used, should then be correlated to an exposure factor

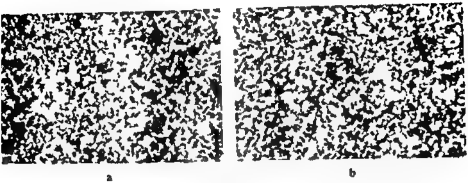

Fig 5 Grid images from two high speed lanthanum oxybromide screens a) Agfa Gevaert MR 600 b) Siemens Titan Tube potential 90 kV The two screens have the same speed and identical MTF Difference in grid image definition due to different microscopic mottles

of 40 when compared with the grid image created by the slower screen Thus if the light output from the background crystal layer is increased in order to yield higher speed unsharpness increases and the relative exposure of the surface crystal layer decreases Increased unsharpness and increased microscopic mottle will thus generally go together However there is no reason to expect them to be very closely linked to each other This statement is illustrated by Fig 5 where two lanthanum oxybromide screens of identical extremely high speed yield a difference in grid image definition Still the same screens displayed identical MTF as measured with the Odeta MTF Analyzer (Oude Delft Holland)

The microscopic mottle and the unsharpness caused by the spread of light can to a certain extent be changed independently of each other if the film speed is altered The MTF then remains constant while it is demonstrated that the mottle changes (Fig 2 c d) In cases where type I definition predominates a high speed screen with a low speed film may be expected to yield an image quality comparable to that of a low speed screen with a high speed film screen film sensitivity being kept constant Low speed films have obvious advantages over high speed ones mainly due to smaller grain size A given amount of silver bromide per square metre of film area gives rise to a greater total amount of silver halide grains when the film speed is low and the grain size is small The number of grains per unit area appears to determine the information storage capacity of the film (SELIN et coll 1975 SELIN & REICHMANN 1977 REICHMANN et coll ROSE STERNGLASS et coll DAINTY & SHAW 1974) The fact that the recording of small details in high speed radiography seems to be largely noise limited offers an explanation for the clinical observation that radiography with high speed screen and low speed film appears more useful than would be expected from MTF data alone (HÅRDSTEDT REICHMANN et coll)

Unsharpness is generally considered to be independent of the spectral distribution of the radiation (ROSSMANN 1966) This is to be expected in situations where the MTF is determined mainly by the diffusion of light emitted by the screen However

a reabsorption of secondary radiation emitted by the screen itself also occurs which has been demonstrated to contribute to blurring (RIEHL & ZIMMER 1937, KARLSSON 1978). This contribution depends on the tube potential but requires monochromatic radiation to be quantitatively evaluated. The statement by STAPLETON (1976) that unsharpness is only slightly affected by the quality of the radiation, the visible effect of increased tube potential being mainly attributed to a change in contrast, appears widely accepted. However, the present results provide further reason to question this traditional standpoint that resolution and unsharpness should be independent of tube potential and other factors influencing the spectral distribution of the radiation. Since noise factors seem to be of decisive importance for resolution capacity besides the spread of information described by the MTF, the resultant effect is a direct influence of the wave length of the radiation on resolution capacity.

The modulation transfer function is a well defined parameter which may be measured with great reliability and expressed in the form of a comprehensive frequency response curve. The influence of noise factors on image quality are not so easy to measure and to express. This discrepancy implies that it is easy to overestimate the MTF so that it is applied in situations where it is not valid with regard to the conclusions drawn. Many radiographic components are marketed with a quality declaration mainly based on the MTF; this applies above all to intensifying screens. The general radiologist may become so impressed by the advanced technique underlying the MTF evaluation that he forgets to look at the actual images produced by the screens he is offered to purchase. The opinion is often heard that the MTF represents the objective information while inspection is subjective. True, the MTF yields objective information, but only about one factor influencing image quality, to an unknown degree, while inspection, although being subjective, provides an estimate concerning all the factors determining radiographic information capacity. A great deal of further research is necessary before the interaction between the MTF and the different kinds of noise giving rise to type I may be quantitatively assessed. Until then—and probably even afterwards—an inspection technique is needed where the subjective element is reduced as far as possible. The after treatment of films used in the present tests (contact copying with subsequent enlargement on hard working film) raises critical details well above the thresholds of vision, thus making inspection more reliable. In this clinic this procedure has been used in comparisons between films obtained in practice from the same object with different radiographic techniques. An enlargement of about 5 times then appears useful. That inspection may indicate preference for a screen which has not the best MTF was demonstrated by HOLJE & SVAHN (1974) who recorded the MTF for a great variety of screens. Films produced with the same screens were demonstrated without enlargement or any other after treatment to a group of inspectors composed of radiologists and laymen. One screen film combination in the high speed class was clearly preferred although the MTF for the screen in question did not emerge as especially favourable. The initial conclusion drawn by many readers of the report was that it proved inspection to be inferior to

objective quality tests However the demonstration in the present investigation that microscopic mottle may influence definition in a way not previously realized offers an alternative explanation for the discrepancy between the two methods of quality evaluation

SUMMARY

By a special technique of enlarging films a microscopic mottle caused by quantum fluctuations was demonstrated It was found to affect depiction of small details in such a way as to suggest that it would be of importance for determining resolution capacity especially in high speed radiography Thus the modulation transfer function appears not to be the only factor determining radiographic resolution The resolution of high speed screens may be improved if the film speed is reduced which leads to a diminished microscopic mottle

ZUSAMMENFASSUNG

Durch eine spezielle Technik von Filmvergrosserung wurde ein mikroskopisches Flimmern hervorgerufen durch Quanten Fluktuationen nachgewiesen Es wurde gefunden dass dieses die Abbildung von kleinen Details in einer solchen Weise beeinflusst dass vermutet werden kann dass dieses von Bedeutung fur die Bestimmung der Auflosungskapazitat ist besonders bei Radiographie mit schnellen Verstarkerfolien Somit scheint die Modulations-Transfer Funktion nicht der einzige Faktor zu sein der die rontgenologische Auflosung bestimmt Die Auflosung von schnellen Schirmen kann verbessert werden wenn die Filmgeschwindigkeit herabgesetzt wird was zu einer Verminderung des mikroskopischen Flimmerns fuhrt

RÉSUMÉ

Grace a une technique speciale d agrandissement des films les auteurs ont mis en évidence un grain microscopique causé par la fluctuation quantique Les auteurs ont constaté que ce grain influe à tel point sur la représentation de petits détails qu il leur parait important pour determiner la capacite de resolution en particulier en radiographie à grande vitesse Ainsi la fonction de transfert de modulation ne parait pas etre le seul facteur determinant la resolution radiographique La resolution d ecran rapide peut etre amelioree si la rapidité du film est reduite ce qui aboutit à une diminution du grain microscopique

REFERENCES

DAINTY J and SHAW R Image science Principles analysis and evaluation of photographic type imaging processes Academic Press London 1974

HÅRDSTEDT C Personal communication 1978

HOLJE G och SVAHN G Test av forstarkningsskarmar (In Swedish) SPRI Report No 6030 9 (1974)

KARLSSON M Personal communication 1978

REICHMANN S HELANDER C G and SELIN K Medichrome film as an alternative to silver free recording systems Acta radiol Diagnosis 19 (1978) 513

RIEHL N und ZIMMER K G Untersuchungen uber die Zeichenscharfe von Verstarkerfolien aus verschiedenen Materialen Fortschr Rontgenstr 55 (1937) 386

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The modulation transfer function is a well defined parameter which may be measured with great reliability and expressed in the form of a comprehensive frequency response curve The influence of noise factors on image quality are not so easy to measure and to express This discrepancy implies that it is easy to overestimate the MTF so that it is applied in situations where it is not valid with regard to the conclusions drawn Many radiographic components are marketed with a quality declaration mainly based on the MTF this applies above all to intensifying screens The general radiologist may become so impressed by the advanced technique underlying the MTF evaluation that he forgets to look at the actual images produced by the screens he is offered to purchase The opinion is often heard that the MTF represents the objective information while inspection is subjective True the MTF yields objective information but only about one factor influencing image quality to an unknown degree while inspection although being subjective provides an estimate concerning all the factors determining radiographic information capacity A great deal of further research is necessary before the interaction between the MTF and the different kinds of noise giving rise to type I may be quantitatively assessed Until then—and probably even afterwards—an inspection technique is needed where the subjective element is reduced as far as possible The after treatment of films used in the present tests (contact copying with subsequent enlargement on hard working film) raises critical details well above the thresholds of vision thus making inspection more reliable In this clinic this procedure has been used in comparisons between films obtained in practice from the same object with different radiographic techniques An enlargement of about 5 times then appears useful That inspection may indicate preference for a screen which has not the best MTF was demonstrated by HOLJE & SVAHN (1974) who recorded the MTF for a great variety of screens Films produced with the same screens were demonstrated without enlargement or any other after treatment to a group of inspectors composed of radiologists and laymen One screen-film combination in the high speed class was clearly preferred although the MTF for the screen in question did not emerge as especially favourable The initial conclusion drawn by many readers of the report was that it proved inspection to be inferior t

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OPTIMISED TOMOGRAPHY FOR CLINICAL USE

K ÅSTRAND and S REICHMANN

Tomography has been practised clinically for about fifty years During that time several philosophies have been developed about the proper construction of the tomographic movement and about how to measure and express the influence of various tomographic movements on tomographic depiction (ZIEDSES DES PLANTES 1932 BARTELINK 1933 GROSSMANN 1935 a b EDHOLM 1960 WESTRA 1966 MATTSSON 1972 HALS et coll 1973 HARDING & DAY 1976) The present authors (REICHMANN 1972 ÅSTRAND & REICHMANN 1974 HELANDER et coll 1977) have described and tested a new principle for optimising tomographic depiction Optimum conditions were established by analysing the blurring of a sharp edge situated outside the tomographic plane The intention was to reach a state where the zone of blurring was visually appreciated as smooth so that in fact a real blurring occurred without any spurious contours appearing It was found that the larger the attenuation difference across the sharp edge the more difficult it was to meet the requirements of optimum conditions In the cases tested a metal plate was used for this object a spiral movement path of ten revolutions was found to be necessary It was also found that the revolutions within the spiral had to be arranged in a certain way and furthermore the different revolutions had to be combined with different exposure rates This type of tomographic motion was tested in clinical situations using screen film combinations as well as xerographic plates as recording medium The latter were found to yield excellent tomographic depiction with an optimised tomographic movement whereas the same plates tended to yield such a disturbing depiction of the spurious

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ROSE A Vision Plenum Press New York 1973
ROSSMANN K Comparison of several methods for evaluating image quality of radiographic screen film systems Amer J Roentgenol 97 (1966) 772
— Image quality Radiol Clin N Amer 7 (1969) 419
SELIN K and REICHMANN S High density failure of radiographic films Acta radiol Diagnosis 18 (1977) 95
— — Visual evaluation of microscopic mottle Acta radiol Diagnosis 20 (1979) 551
— DEICHGRABER E and REICHMANN S Influence of secondary radiation on image quality Acta radiol Diagnosis 16 (1975) 520
STAILETON R E Image quality in X ray systems X ray Focus 14 (1976) 46
STERNGLASS E J SASHIN D and HEINZ E R Electronic imaging in diagnostic radiology *In* Current concepts in radiology Volume 2 Chapter 5 p 75 Edited by E J Potchen Mosby Saint Louis 1975

Table

Survey of the different simulated spirals tested composed of 4 or 5 revolutions

Four revolutions			*Five revolutions*		
Relative radius	Exposure/revolution		Relative radius	Exposure/revolution	
	Fixed	Variable		Fixed	Variable
1 00	0 25	0 [illegible]0	1 00	0 20	0 10
0 74	0 25	0 31	0 79	0 [illegible]0	0 25
0 48	0 25	0 31	0 59	0.20	0 30
0 [illegible]	0 25	0 18	0 38	0 20	0 25
			0 17	0 [illegible]0	0 10

which in principle will lead to more complete optimisation of the tomographic blurring The 4 *types of optimised movements tested are presented in the* Table

The middle and inner ear of a skull phantom embedded in plastic was exposed at 120 kV no additional filtration being used The *movements presented in the* Table all had a tomographic angle of 20 They were compared with circular tomography of the same tomographic angle and with optimised tomography of 20 using a movement of 10 revolutions previously demonstrated to yield perfect tomography In addition hypocycloid tomography of 48 was carried out The 7 types of tomographic movement mentioned were all carried out in 4 cut section planes through different levels of the ear The Rank Xerox plates were charged and developed as before *Furthermore the same number of movements and section planes were obtained* by means of screen film radiography using Kodak X omatic Regular screens and Agfa Gevaert Curix RP 1 *film Tube potential in this case was 60 kV* The tomographic planes of xerotomography did not coincide with those of screen film tomography owing to differences in the construction of the cassettes

As expected xerographic tomography displayed the differences in blurring caused by the different tomographic movements much more clearly than did screen film *tomography* The 4 different simulated spirals of 4 or 5 revolutions gave a clear improvement in blurring as compared with circular tomography (Figure) However the quality of *blurring was still somewhat imperfect* for the movements of 4 revolutions whereas the movement comprising 5 revolutions with a variable exposure rate gave rise to a blurring which did not significantly *deviate from that of* the idealised movement of 10 revolutions (Fig c d)

Discussion

The aim of the present experiments was to design a tomographic movement yielding as good a blurring as possible in ordinary clinical tomography Obviously this aim presupposes a compromise between what is to be gained from an *increased* number of *revolutions* of the tomographic movement and what is to be lost in the

contours always appearing in circular tomography as to be of little use in this type of tomography. In fact the xerographic plates in conjunction with the optimised tomographic movement were found to permit a nearly perfect tomographic depiction, partly due to the contrast levelling inherent in the xeroradiographic principle (BOAG 1973).

Technically, it appears impossible to construct a tomograph capable of 10 revolutions within an acceptable exposure time without its stability being jeopardized. However, the optimisation procedure leading to this complex type of movement path was based on tomography of a sharp edge of such a great attenuation difference as is only rarely encountered in clinical radiography. Therefore it appeared reasonable to assume that the same type of tomographic depiction would be obtainable for ordinary clinical objects with a movement path of fewer revolutions. This theory has been tested and the results are now reported. Optimisation was performed for the middle and inner ear, and, since xerographic plates were previously found to be the most sensitive recording medium with regard to appearance and elimination of spurious contours, the tomograms were mainly recorded on plates of this kind.

Experiments

Tomography was performed by means of a Polytome with a nominal focus size of 0.6 mm × 0.6 mm. The different spiral movements were simulated by means of a series of concentric circular movements obtained with the zonography equipment, making possible any tomographic angle between 0° and 20°. Recording was made on Rank Xerox radiographic plates. Before the exposure the plates were given the highest charge and development was arranged to give a positive image.

Previous (unpublished) results indicated that tomographic movements of 4 or 5 revolutions should be sufficient for optimum depiction of the ear. Before skull tomography was initiated, a number of sharp edge tomograms with a metal plate were carried out in order to establish a reasonably small number of different tomographic movements for the final test. Different movements of 3, 4 and 5 revolutions were calculated according to ÅSTRAND & REICHMANN and were applied to tomography of the sharp edge. The metal plate giving rise to this edge was slanted against the tomographic plane, coinciding with this plane at one end so that in one and the same tomogram the depiction of the sharp edge within the tomographic plane could be compared with the blurring of the edge at different distances from the tomographic plane. The metal plate was exposed at 110 kV using 1.4 mm additional Cu filtration. This series of tomograms indicated that there is a great difference between tomographic movements of 3 revolutions and more complex movements. In skull tomography, therefore, only movements of 4 and 5 revolutions were tested. These movements were of two kinds. In one type the same exposure rate was used for all revolutions, the geometric conditions of the movements being arranged so as to give the best depiction possible. In the other type a variable exposure rate was introduced.

new type of equipment called Optiplanimat this company has succeeded in constructing a tomograph performing 5 revolutions in as short a time as 5 s tomographic angle 45 without stability being jeopardized (GEBAUER 1978 ULBRICHT 1978) Thus 5 revolutions can actually be performed Since this number was found to yield optimum performance in ear tomography there seems to be no reason to recommend tomographic movements of fewer revolutions A difference between the recommended tomographic movement and simpler ones is more difficult to discern in screen film tomography than in xerographic tomography which more directly reflects the actual difference inherent in the radiation relief However it may be expected that recording media working analogously with the xerographic medium but having better sensitivity will be obtained in the near future When tomographs are constructed today it seems advisable that the movement path should be given such a high degree of refinement that electroradiographic recording systems may be used

SUMMARY

A technique elaborated by the present authors (1974) for the establishment of optimum tomographic movements was applied to ear tomography in order to design a movement that is not too complex but yielding good tomographic depiction Such a movement was found to consist of a spiral of 5 revolutions Modern engineering appears to allow such complex movements to be carried out with satisfactory stability within a reasonable exposure time

ZUSAMMENFASSUNG

Eine Technik wurde von den beiden Verfassern (1974) zur Feststellung von optimalen Tomographie Bewegungen ausgearbeitet und bei der Ohren Tomographie verwendet in der Absicht eine Bewegung hervorzurufen die nicht zu komplex ist jedoch eine gute tomographische Bilddarstellung erzielt Eine solche Bewegung wurde bei einer Spirale von 5 Drehungen gefunden Die technische Entwicklung der Apparatur erlaubt solche komplexe Bewegungen mit zufriedenstellender Stabilität und Expositionszeit auszuführen

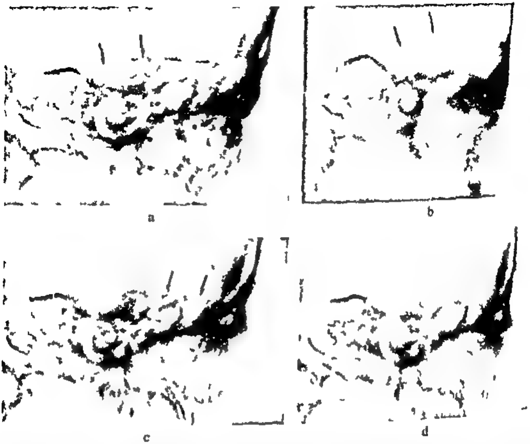
RESUMÉ

Une technique élaborée par les auteurs (1974) pour établir un mouvement tomographique optimal a été appliquée à la tomographie de l oreille pour définir un mouvement qui n est pas trop complexe mais qui donne une bonne image tomographique Ce mouvement consiste en une spirale a 5 revolutions L ingénieering moderne permet de produire des mouvements complexes de ce type avec une stabilité satisfaisante et un temps d exposition raisonnable

REFERENCES

ÅSTRAND K and REICHMANN S Optimised tomography Theoretical and practical analyses of the elimination of depiction errors in tomography Acta radiol (1974) Suppl No 338

BARTELINK D L Röntgenschnitte Fortschr Röntgenstr 47 (1933) 399



Xerographic tomography of the same plane through the ear of a skull phantom embedded in plastic. In (a), (c) and (d) the tomographic angle was 20°, in (b) 48°. The movement path was circular (a), hypocycloid (b), simulated spiral of 4 revolutions, constant exposure rate (c) and simulated spiral of 5 revolutions, variable exposure rate (d). The superior margin of pars petrosa is situated outside the plane but is still depicted by sharp contours (→) in (a), (b) and (c). Other spurious contours referring to structures outside the tomographic plane also appear, being eliminated in (d).

stability of the tomographic movement when its complexity is increased. As test object the middle and inner ear was chosen since demands on tomographic image quality are especially high for this organ. Furthermore, xerographic plates were used being particularly well suited to demonstrate defects in blurring quality. Such plates are not suitable for tomography at present owing to their low sensitivity. However, it may be expected that similar recording media will be constructed having more favourable properties. Under the prevailing conditions it was found that a tomographic movement of 5 revolutions yields such a good blurring that more complex movements are superfluous. The exposure rate of the tube was not constant. However, variable exposure is easy to accomplish and does not interfere with the practical problem of the stability of the tomograph.

A spiral movement of 5 revolutions within a reasonable exposure time is not obtainable in most present day tomographs. The present experiments have been carried out in some cooperation with Siemens (Erlangen, West Germany). In designing

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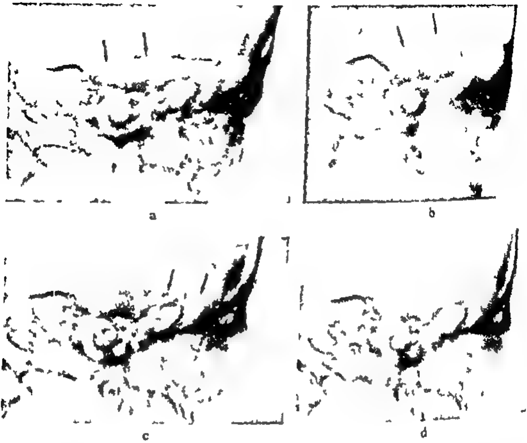
BARTELINK D L Rontgenschnitte Fortschr Rontgenstr 47 (1933) 399



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REFERENCES

ÅSTRAND K and REICHMANN S Optimised tomography Theoretical and practical analyses of the elimination of depiction errors in tomography Acta radiol (1974) Suppl No 338

BARTELINK D L Rontgenschnitte Fortschr Rontgenstr 47 (1933) 399

BOAG J W · Xeroradiography Phys in Med Biol 18 (1973) 3
EDHOLM P The tomogram Its formation and content Acta radiol (1960) Suppl No 193
GEBAUER A Radiologisch klinische Erfahrungen mit dem Optiplanimat Electromedica 4 (1978) 128
GROSSMANN G (a) Tomographie I Röntgenographische Darstellung von Korperschnitten Fortschr Rontgenstr 51 (1935) 61
— (b) Tomographie II Theoretisches uber Tomographie Fortschr Rontgenstr 51 (1935) 191
HARDING G and DAY M J Blurring quality in spiral tomography Acta radiol Ther Phys Biol 15 (1976) 465
HAUS A COLLINS P and ROSSMANN K A method of measuring image degradation in tomography Radiology 109 (1973) 219
HELANDER C G REICHMANN S and ÅSTRAND K Xerographic tomography Acta radiol Diagnosis 18 (1977) 369
MATTSSON O · Formation of the tomographic image With special reference to blurring Acta radiol (1972) Suppl No 318
REICHMANN S Modified theory of the development of tomographic blurring Acta radiol Diagnosis 12 (1972) 457
ULBRICHT A Die Bewährung des Rontgenschichtaufnahmegerätes Optiplanimat in der täglichen Routine Electromedica 4 (1978) 133
WESTRA D Zonography The narrow angle tomography Excerpta Medica Foundation Amsterdam 1966
ZIEDSES DES PLANTES B G Eine neue Methode zur Differenzierung in der Rontgenographie (Planigraphie) Acta radiol 13 (1932) 182

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TOMOGRAPHIC LOCALIZATION OF MOTION AXES

ANNE HENNING and SVEN REICHMANN

In every synovial joint at least one motion axis exists even if the movement is translatory although in that case at an infinite distance In clinical treatment of disorders of the locomotory system precise knowledge as to the position of different motion axes may be of great importance This is illustrated by ROLANDER s (1966) investigation of how the position of motion axes in the lumbar spine was affected by posterior fusion He could then outline principles for more effective immobiliza tion of unstable segments of the lumbar spine The position of the motion axes can be determined in postmortem specimens as well as in living subjects In both cases a radiographic technique may be used Generally an in vivo technique is to be preferred since it may be difficult to imitate the natural muscular activity by means of external forces applied to a bone and joint specimen Radiography as a rule offers the only feasible method in humans

It might be expected that films exposed at the beginning and end of the movement would be sufficient for determination of the position of the motion axis However with a conventional technique the joint motion inevitably leads to changed radio graphic *projection* and so the images obtained are not directly comparable Thus the difference between the images does not only define the motion around the axis to be localized it reflects projection differences as well Since these two factors can not be evaluated *separately* the technique mentioned is not satisfactory The influence of changed projection may be established by means of roentgen stereophotogram

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BOAG J W Xeroradiography Phys in Med Biol 18 (1973) 3
EDHOLM P The tomogram Its formation and content Acta radiol (1960) Suppl No 193
GEBAUER A Radiologisch klinische Erfahrungen mit dem Optiplanimat Electromedica 4 (1978) 128
GROSSMANN G (a) Tomographie I Rontgenographische Darstellung von Korperschnitten Fortschr Rontgenstr 51 (1935) 61
— (b) Tomographie II Theoretisches über Tomographie Fortschr Rontgenstr 51 (1935) 191
HARDING G and DAY M J Blurring quality in spiral tomography Acta radiol The Phys Biol 15 (1976) 465
HAUS A COLLINS P and ROSSMANN K A method of measuring image degradation in tomography Radiology 109 (1973) 219
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MATTSSON O Formation of the tomographic image With special reference to blurring Acta radiol (1972) Suppl No 318
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ULBRICHT A Die Bewährung des Rontgenschichtaufnahmegerates Optiplanimat in de täglichen Routine Electromedica 4 (1978) 133
WESTRA D Zonography The narrow angle tomography Excerpta Medica Foundation Amsterdam 1966
ZIEDSES DES PLANTES B G Eine neue Methode zur Differenzierung in der Rontgenographie (Planigraphie) Acta radiol 13 (1932) 182

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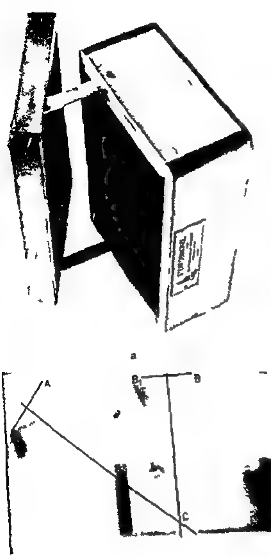


Fig 1 a) A test object with two independent motion axes b) Localization of the resultant motion axis when the object in (a) has been moved around both of its motion axes The object itself appears in one end position of the movement In localizing the axis position it is assumed that the lid has been moved while the box itself has not When the two tomograms describing the motion were superimposed two points of the lid were found to have moved from A to A and B to B respectively Lines were drawn between these points The bisecting normals to these lines cross at the site of the resulting motion axis (C) Since the motion has taken place around two axes simultaneously the position of the resultant axis does not coincide with either of them

forating both of them with a thin needle At least two such corresponding points are needed These perforations do not have to be made through the image of the superimposed object detail They may be placed far outside it and yet be used to describe the reciprocal orientation of the object detail in the two images In this way one moving component has been localized by means of corresponding image points in two films The superimposition procedure is then performed for the other component as well When the films are reoriented for this secondary superimposi

metry (HALLERT 1970). This technique implies that two images are exposed with a known and standardized projection difference before and after the movement, forming stereoscopic image pairs. Unfortunately, this technique has certain important disadvantages. A detailed analysis of the difficulties and sources of error inherent in roentgen stereoscopy was carried out by WESTRA (1966). In roentgen stereoscopy the stereoscopic information is obtained only from image contours. In stereoscopy of conventional photographs, on the other hand, information of depth may be obtained from every point in the image. This peculiar quality makes roentgen stereoscopy more difficult to employ, albeit not impossible. However, for photogrammetric measurements considerable problems are involved. When the displacement of projection leading to stereoscopic image pair formation is introduced, different surfaces within the object will give rise to the contours. Therefore, to a large extent, these contours do not refer to identical points in the object, which may preclude measurements. This problem may be circumvented if measurements are restricted to very small object details (HOLLENDER 1964, OLIN et coll. 19 6). Insofar as natural reference points of such a kind do not appear in the object, small markers of metal may be inserted before roentgen stereophotogrammetry (Olsson et coll. 1976). However, this cannot be adopted as a standard procedure for examination of joint function. This applies especially to deeply situated joints and joint systems with several differently moving components.

Previously, an alternative method for determination of motion axes has been presented by REICHMANN et coll. (1972). Instead of two stereoscopic image pairs, a tomogram was exposed before and after subject motion, using multidirectional tomography with a large tomographic angle. It was assumed that within certain limits, determined by the movement path of the focus, the object might perform translatory movements between the two recordings without affecting the image. The differences in the tomograms were therefore considered to be related only to object motion around the axis to be determined. However, this hypothesis was not tested experimentally. This has now been done and the results are presented in this communication.

Methods

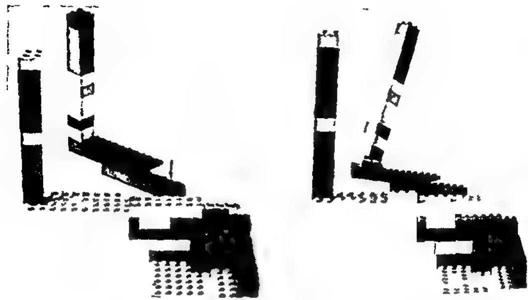
Two tomograms, describing the motion of the object, are assumed. One is taken in the initial and the other in the final position. They represent the same tomographic plane through the object. One tomogram is contact-copied onto film which is developed to a gamma value of 1.0. Provided the two original tomograms have the same contrast, the copy thus obtained may be superimposed on the other tomogram, in such a way as to extinguish the image of some components in the moving system. In those image parts which are thus extinguished, each point of one film is directly projected onto the corresponding point in the other. Such corresponding points may therefore be marked in the superimposed film by p

Polytome was used tube potential 54 kV filtration 1 2 mmCu Hypocycloid ›vement 48 was used except in certain cases Recording was made on Curix RP 1 m (Agfa Gevaert) with Kodak X omatic Regular screens

In the first experiment the model was translated 13 cm sideways between the posures describing the movement around the motion axis The position of the otion axis was determined and compared with values obtained in the same way thout any translatory movement as well as with the model itself The reproduci lity of the photographic method was determined From one motion recording wo tomograms) 10 separate axis position determinations were carried out In e final films the distance between the centre of the moving vertical column and ie axis was measured the values obtained being corrected for the constant magni cation of the Polytome (1 34 times) The experiments resulted in a distance of 37±3 7 mm the actual value was 136 mm Thus the technique was useful in spite f the translatory movement of the object When it was attempted to determine the iotion axis position from conventional films the same translatory movement was ›und to make the films recording the rotary movement completely incomparable n other words tomography was indispensable

In a second experiment the rectangular columns of the test phantom were replaced ›y cylindrical ones but the experiment was otherwise performed in the same way However the films could not be evaluated since the two images of one column could cover each other in many different ways The two films could be rotated against each other around an axis coinciding with the cylinder axis of the column in which case no corresponding image points could be defined Thus object details giving rise to completely circular images in the tomogram may render evaluation of the films impossible and the present technique thus cannot be used In a third experiment rectangular columns were used again but one of the columns was not vertically positioned but slanted (Fig 2 b) Tomographic recordings were made without the model being moved in the horizontal plane between the exposures Instead the phantom was moved vertically so that the tomographic plane passed through the phantom at one level before the rotation was started and through another level when it was finished Since the two columns were not parallel this displacement of the tomographic plane could be expected to give rise to a source of error in the localization of the motion axis position The distance from the centre of the moving column to the motion axis was shown to be 158±1 7 mm Thus the experiment indicated that the position of the motion axis cannot be tomographically located if there is reason to suppose translatory movements of the object in a direction per pendicular to the tomographic plane during the movement to be analysed

During certain rotations in the living subject several motion axes operate simultaneously Therefore two separate experiments simulating such a case were performed In the first of these the test phantom with the two rectangular columns parallel with each other was used A movement was initiated around the vertical axis of one column At the same time the whole phantom was rotated around a



a b

Fig 2 Test phantom with two vertical columns having a quadrangular cross section area a) One of the columns may be rotated along a vertical axis (→) b) The movable column is not vertical but slanted

tion the perforations first made will be separated from each other in a way determined by the object motion The displacement of each pair of corresponding points is marked by a straight line on one film Thus two such lines are obtained bisecting normals being constructed The intersection point of these normals lies where the motion axis passes through the tomographic plane The procedure is illustrated in Fig 1 The object was a wooden box with a moving cover (Fig 1 a) The first superimposition concerned the images of the cover, resulting in two perforations The images of the box were then superimposed the perforations being separated along the straight lines The bisecting normals of these lines coincide at the place of the motion axis

Experiments

The method mentioned was tested in a series of experiments In the first four tests a simple object was used (Fig 2 a) consisting of two vertical columns each resting on a horizontal arm One arm was turnable together with its vertical column around an axis near its base The tomographic plane passed through the vertical columns in such a way as to make the site of the motion axis invisible on the tomograms Instead when the location of the motion axis was determined from the tomograms it could be compared with the actual site in order to test the validity of the method Tomography was carried out under varying conditions particularly under conditions in which the method was expected to give erroneous information

determined The object must not be translated in a direction perpendicular to the tomographic plane during the movement Preferably the object should not rotate around an axis parallel to the tomographic plane However very small rotations of this kind do not seem to give rise to any important source of error Furthermore another disadvantage not touched upon earlier is the fact that the tomographic image is not perfectly sharp Thus superimposing two tomograms so as to make the images cover each other completely is a procedure with a certain degree of inexactness This is most obvious when the moving structures are small giving rise to low contrast This complication can be overcome to a certain extent by means of repeated examinations of the original images In those cases where roentgen stereophotogrammetry can be carried out a complete three dimensional determination of the geometry of the whole object is obtained The present method primarily gives information only about the movement in the tomographic plane This shortcoming can be counteracted by means of simultaneous multisection tomography This technique implies the use of several screen film combinations on top of each other recording different tomographic planes in the object these planes being parallel with each other This has two advantages First it must often be expected that the object moves not only in the tomographic plane but also in a direction perpendicular to it Thus if only one tomographic plane is recorded the technique will be unreliable However if multisection tomography is used it appears possible to compare the same level within the object before and after the movement even if this level is represented by different tomographic planes within the multisection cassette Secondly it is not necessary for the motion axis to be determined to pass through the tomographic plane at a right angle If the localization of the motion axis is carried out at different levels within the object it is possible to find out whether the axis is perpendicular to the tomographic planes or not

SUMMARY

Localization of motion axes within joints and junctures in living humans has been carried out by means of roentgen stereophotogrammetry Another technique is presented here in which the localization of the axis is carried out by means of tomography The field of application for this technique has been examined in a series of phantom experiments It may be employed in certain situations where roentgen stereophotogrammetry is not useful No other equipment is needed than a pluridirectional tomograph and conventional dark room facilities

ZUSAMMENFASSUNG

Die Lokalisation der Bewegungsaxen in den Gelenken und Verbindungen von lebenden Menschen ist mit Hilfe von Rontgenstereophotogrammetrie festgestellt worden Es wird hier eine andere Technik vorgestellt bei der die Lokalisation der Axe mittels Tomographie festgestellt wird Der Umfang der Verwendung dieser Technik ist in einer Serie von Phantmoexperimenten ausgeprobt worden Diese kann in gewissen Situationen wo die Rontgen

horizontal axis parallel with the tomographic plane Thus the columns were vertical in one exposure slanted in the other Since the prolongation of the columns had to pass the plane of the focus within the path of the tomographic motion the object could not be slanted more than 20° against the perpendicular Greater slanting would have made the columns incompletely depicted, so that no evaluation would have been possible Consequently the source of error was found to be comparatively small The distance to the motion axis from the centre of the moving column was in this case determined to be 131 ± 3 8 mm This figure was obtained from five separate determinations The experiment demonstrates that small rotations along an axis parallel with the tomographic plane will not usually give rise to great displacements of the motion axis However such rotations constitute a potential source of error its effect has to be estimated from case to case

In the last experiment another phantom was used (Fig 1 a) The two moving components could rotate simultaneously along two parallel motion axes both of perpendicular to the tomographic plane The object was exposed in several positions (Fig 1 b) For each image pair a motion axis was determined as if there had in fact been only one axis In spite of the motion along two axes it was found possible in all cases to define a resulting motion axis which fully described the combined movement of the two components This motion axis did not coincide with either of the two actual motion axes On the contrary it was in many cases situated far away from them Thus if the movement takes place around several axes simultaneously these axes cannot be defined separately In all cases however, a resulting motion axis may be defined

Discussion

The position of different motion axes in the different parts of the locomotory apparatus as described in textbooks has to a large extent been based upon anatomic investigations of autopsy specimens Reconstructive orthopedic surgery as well as physiotherapy is partly based on such descriptions For lack of suitable techniques information on these axes has not usually been obtainable from living humans in health or disease The method presented here by no means offers a final solution to the problems since several sources of error may influence the evaluations made However in certain situations it may yield information where other techniques fail

The present technique has one major advantage since it can be employed in many cases in which stereophotogrammetry cannot be used without insertion of small metallic indicators Furthermore the technique is simple, demanding no special equipment for the examination of the images as is the case in stereophotogrammetry The tomograph with pluridirectional movement is available in most large radiography departments However the method also has certain drawbacks The moving structures must not give rise to circular configurations in the tomograms since in such a case the internal orientation between the image pairs cannot be

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IMAGE ENHANCEMENT BY DIGITAL-ANALOG FILTRATION

III Experiences with bone metastases

A HEMMINGSSON B JUNG H LUNDQVIST and A STRÖMLID

The conventional roentgenogram is rich in detail and sometimes the large amount of information presented may render the evaluation difficult This is true for example in the diagnosis of bone metastases where disturbing structures of spongy bone are superimposed upon the metastasis and reduce its perceptibility

Reduced reproduction of the bone trabeculae with remaining contour and contrast of the metastases is therefore desirable This should be possible to achieve by frequency filtration as spongy bone has higher spatial frequencies than round soft tissue structures (ROSSMANN 1968 KUNDEL et coll 1969 1972 ROSSMANN & MOSELEY 1969 ZISKIN et coll 1971 ROCKOFF 1972 HEMMINGSSON et coll 1972) In the present report the result of frequency filtration of films with overlooked bone metastases is described

Material and Methods

Films of 10 patients in whom bone metastases were overlooked at the first radiography were frequency filtered In all cases the metastases were difficult to perceive even in retrospect with assess to films taken 2 to 6 months after the primary examina

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stereophotogrammetrie nicht möglich ist verwendet werden Es wird keine andere Ausrustung gebraucht als ein pluridirektionaler Tomograph und gewohnliche Dunkelraum-Ausstattungen

RÉSUMÉ

La localisation des axes de mouvements dans les articulations et les jointures chez les humains vivants a été effectuée par stéréophotogrammétrie radiologique Les auteurs présentent ici une autre technique dans laquelle la localisation de l axe est effectuée par tomographie Ils ont examiné le champ d application de cette technique sur une série d expériences sur fantomes Cette technique peut être utilisée dans certaines situations ou la stéréophotogrammétrie radiologique n est pas utile Elle ne nécessite pas d autre equipement que la tomographie multidirectionnel et les installations d une chambre noire traditionnelle

REFERENCES

HALLERT B X ray photogrammetry Basic geometry and quality Elsevier Amsterdam 1970
HOLLENDER L Determining the elements of the interior orientation in roentgenography Acta radiol (1964) Suppl No 230
REICHMANN S BERGLUND E und LUNDGREN K Das Bewegungszentrum in der Lendenwirbelsäule bei Flexion und Extension Z Anat Entwickl Gesch 138 (1972) 283
ROLANDER S D Motion of lumbar spine with special reference to the stabilizing effect of posterior fusion Thesis Gothenburg 1966
OLIN T OLSSON T H SELVIK G and WILLNER S Kinematic analysis of experimentally provoked scoliosis in pigs with roentgen stereophotogrammetry Acta radiol Diagnosis 17 (1976) 107
OLSSON T H SELVIK G and WILLNER S Vertebral motion in spondylolisthesis Acta radiol Diagnosis 17 (1976) 861
WESTRA D Zonography Excerpta Medica Foundation Amsterdam 1966

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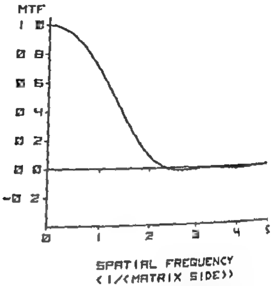


Fig 1 The modulation transfer function of the filter used

tion for comparison Eight of the patients had predominantly osteolytic lesions 7 of them arising from carcinoma of the breast and one from an Ewing sarcoma Two cases of sclerotic metastases arose from carcinoma of the prostate In 8 of the patients the overlooked metastases were in the pelvis or the proximal part of the femur and in the other 2 in the skull

The device for image enhancement with a digital filter described in Part I (CEDERLUND et coll 1979) was used The filter has low pass characteristics with a cut off frequency of about 1 mm^{-1} which previously (Part II HEMMINGSSON et coll 1979) had been found to give promising experimental results The modulation transfer function of the filter appears in Fig 1 The filtered film was recorded on the green light sensitive film Trimax XM (3M)

The original film and the filtered film were also superimposed in order to further improve the perceptibility of the metastases The superimposed film was recorded by direct copying on the positive duplicate film RP/X omat (Kodak) with a gradient of 1 1 on a BXR Mk II (Bluray Inc) automatic copying machine and the film was developed in a 90 s automatic developing machine

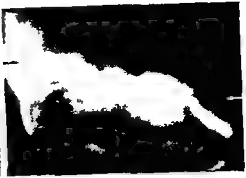
Microdensitometry of the original and the filtered film in a line crossing the metastases was also performed with the microdensitometer Mark III CS (Joyce Loebl)

Results

In all cases the metastases were more clearly visible on the filtered film than on the original (Figs 2 4) and in some cases additional metastases were observed on the filtered film When the filtered and the original film were superimposed the metastases appeared even more distinctly due to the increased difference in contrast (Fig 4c)

Microdensitometry of the films revealed that the contrast of the small spongy bone structures was considerably lower on the filtered film while that of the more extended

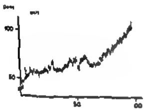
a



b

c

Fig 2 a) Original film with overlooked sclerotic bone metastases b) Same film after filtration c) Appearance 4 months later



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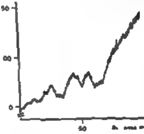

b

Fig 3 a) Same case as in Fig 2. Microdensitometry of the original film Scan line indicated by arrows in Fig 2 a b) Microdensitometry of the same film after filtration Scan line indicated by arrows in Fig 2 b

metastasis was essentially unchanged after filtration (Figs 3 5) Microdensitometry of the superimposed film copy showed that on this copy the contrast of the metastasis was about twice as great as on the original film (Fig 5)

Discussion

The better perceptibility of the metastatic lesion on the filtered film than on the original one is due to the fact that the high frequ ncy disturbance by the spongy bone is largely eliminated after the filtration procedure If the image of the spongy

Fig. 4. a) Original film with an overlooked osteolytic bone metastasis. b) Same film after filtration. c) Copy of the superimposed original and filtered films. d) Metastasis in the area of the trochanter major 3 months later.

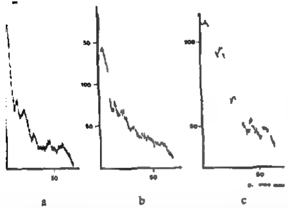

Fig 5 Same case as in Fig 4 a) Microdensitometry of the original film Scan line indicated by arrows in Fig 4 a b) Microdensitometry of the same film after filtration Scan line indicated by arrows in Fig 4 b c) Microdensitometry of the superimposed original and filtered film copy Scan line indicated by arrows in Fig 4 c

ne is regarded as noise and the difference in contrast between the metastasis and surrounding area as a signal of the metastasis then the signal to noise ratio is ger in the filtered film than in the original due to a reduction of the interference the spongy bone This ratio can also be raised by increasing the signal of the meta isis which is achieved on the sup rimposed film copy by linear addition of the ntrast differences in the two films (MILLER 1975) The more than doubling of the ntrast of the metastasis was due to the fact that the copying film used had a gradient 1 1 An effect similar to that obtained on superimposition can b produced by ocessing with the present device In order to increase the signal to noise ratio ■ to improve the p rceptibility of the metastasis it is necessary to degrade the image the spongy bone by for example frequency filtration

The results support the previously presented hypothesis that low pass filtering can nprove the diagnostic possibility in cases of bone metastasis (HEMMINGSSON et coll 972) It should be noted that only a rough attempt was made to idealize the pro- rties of the filter in relation to the task at hand The long scanning time—about ne hour for a 24 cm × 30 cm film—means that the device is of limited applicability or routine use in its present form However it can be made considerably faster An lternative ■ to use a TV technique in the image enhancement procedure or to carry out the filtering already in the intensifying screens

SUMMARY

Frequency filtration of films with overlooked bone metastasis in 10 patients improved the perceptibility of the metastases

ZUSAMMENFASSUNG

Eine Frequenz Filtrierung von Filmen bei ubersehenen Knochenmetastasen bei 10 Patienten verbesserte die Darstellung von Metastasen

RÉSUMÉ

La filtration de fréquences de radiographies sur lesquelles des métastases osseuses étaient passées inaperçues chez 10 malades a amélioré la perceptibilité des métastases

REFERENCES

CEDERLUND J HEMMINGSSON A JUNG B LUNDQVIST H and MOBERG H O Image enhancement by digital analog filtration I Technical description of device Acta radiol Diagnosis 20 (1979) 154

HEMMINGSSON A JUNG B and LUNDQVIST H Soft tissue intensification in frontal roentgenography of the larynx Acta radiol Diagnosis 12 (1972) 593

— — — and STRÖMLID A Image enhancement by digital analog filtration II Tests of filters Acta radiol Diagnosis 20 (1979) 665

KUNDEL H L REVESZ G and STAUFFER H M The electro optical processing of radiographic images Radiol Clin N Amer 7 (1969) 447

— ZISKIN M L and SHEA F J The image and its influence on quantitative radiological data Invest Radiol 7 (1972) 187

MILLER F R A multiple film technique for contrast enhancement and/or reduction of patient exposure Radiology 110 (1974) 361

ROCKOFF S D Techniques of data extraction from radiological images Invest Radiol 7 (1972) 206

ROSSMANN K The spatial frequency spectrum A means for studying the quality of radiographic imaging systems Radiology 90 (1968) 1

— and MOSELEY R D Measurement of the input to radiographic imaging systems Radiology 92 (1969) 265

ZISKIN M C REVESZ G KUNDEL H L and SHEA F J Spatial frequency spectra of radiographic images Radiology 98 (1971) 507

Book reviews

HE MEDIASTINUM RADIOLOGIC CORRELATION WITH ANATOMY AND PATHOLOGY By E R
Heitzman C V Mosby Company St Louis 1977

Monographs dealing with the radiology of the mediastinum are scarce This book the companion volume of the well known The lung Radiologic pathologic correlations by the same author is a most welcome contribution Enclosed between the lungs made out of tissues with attenuation properties very close to each other and covered partly by the spine the mediastinum is notoriously difficult to evaluate by conventional radiography Abnormalities must first attain a size which distorts the contours either bulging into the lungs or displacing the esophagus Mediastinal gas constitutes an exception to this rule

The author of the present book has used anatomic preparations i e cadaver sections conventional films linear tomograms and CT images side by side to convey to the reader a thorough understanding of the anatomy of the mediastinum as demonstrated by radiography A number of normal structures or variants are described and the way in which they appear on the film is explained In this respect the book fills an obvious need and is useful also by bringing together the essence of widely scattered investigations reported in the literature While not a comprehensive textbook in the sense that every major fact of anatomy or every important lesion is to be found in it the volume treats a great many of them in some detail The text is easily readable and most of the numerous illustrations are of high quality

In the first chapter the author advocates a new system of anatomic subdivision of the mediastinum in which the aortic and azygos arches play an important role as demarcating lines The classic posterior compartment—the statistically most frequent site of neurogenic tumours—unfortunately disappears The author is aware of this drawback but believes that the advantages of the new system overweigh the disadvantages

For a critical reviewer however it is not difficult to find points on which to disagree It is honest to say that in most cases the divergences in opinion probably reflect differences in tradition between radiologic schools or concern matters of judgement As in most literature from North America tomography is heavily overvalued This technique is recommended e g to demonstrate that an expanding (or stenosing) lesion is situated within the lung (or within a central bronchus) and not in the mediastinum proper In the experience of the reviewer this can in most cases if not all be arrived at on conventional films provided that oblique views are included and the exposures are correct It is certainly legitimate to explore the possibilities and limitations of CT at the appropriate institutions of medical research However it is questionable whether such generous indications for CT in routine work as those proposed in this book can be justified The CT time ought to be saved for intricate problems which cannot be solved by conventional methods

The Scandinavian reader should also be prepared for the fact that the author conforms to that radiologic school which uses metaphors such as lines and stripes when referring to various borders of the lung and also sometimes uses overly vivid expressions such as the spinnaker sail sign or medial closure of the aortic window when meaning simple things such as enlarged thymus or normal lung area just above the entrance of the left pulmonary artery into the lung

These critical remarks refer to some details In most other respects the book is excellent and is worth the reading by all those who in everyday work have to evaluate the mediastinum

Alfred S amosi

CEREBRAL RADIONUCLIDE ANGIOGRAPHY By Frank H DeLand W B Saunders Philadelphia 1976

The book is confined almost exclusively to radionuclide angiography with vertex projection and this must be regarded as a shortcoming The opening chapters contain a comprehensive historical survey and a short but well illustrated account of the vascular anatomy although the chapter on embryology lacks connecting links with the following sections. The strength of the book lies in its abundance of illustrations

A large number of clinical cases are described giving a good idea of the diagnostic characteristics in different types of diseases As the findings are in most cases correlated only with electroencephalography, echoencephalography and the clinical history and not with computer tomography and angiography some doubts are felt on many points regarding the evaluations that are made A more exhaustive documentation of the diagnostic accuracy of the method would have been of value The roentgenologic illustrations which are not very numerous are unsatisfactory In the final chapter the applications of data processing of recorded activity are described in clear and simple language The book is hardly su[illegible] for recommendation to experienced neuroradiologists

Tomas Hindmarsh

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COMPUTER TOMOGRAPHY AS THE PRIMARY RADIOLOGIC PROCEDURE IN ACUTE SUBARACHNOID HEMORRHAGE

JAN BRISMAR

Cerebral angiography especially when performed as a four vessel examination for the evaluation of a subarachnoid hemorrhage is a time-consuming and expensive procedure causing discomfort to the patient and carrying a slight but significant risk of serious complications Computer tomography permits the direct demonstration of blood in the subarachnoid space the ventricular system or the brain parenchyma Several recent reports have demonstrated that this capability of computer tomography may be used for the localization of the bleeding source as well as in predicting the underlying pathology in cases with a subarachnoid hemorrhage (DAVIS et coll 1976 KENDALL et coll 1976 LILIEQUIST et coll 1977 SCOTTI et coll 1977) Computer tomography has therefore been advocated as the primary procedure in an acute subarachnoid hemorrhage (LILIEQUIST et coll SCOTTI et coll)

This statement has been questioned by ALMAANI & RICHARDSON (1978) on the basis that angiography must still be performed Two recent reports (BAHR & HODGES 1978 LARSON et coll 1978) state that the aggregate costs for radiologic procedures in the evaluation of cerebrovascular lesions had increased in their departments after introduction of computer tomography without any concomitant improvement in patient care

The present analysis was performed to evaluate to what extent the routine use of computer tomography as the primary radiologic procedure in cases with acute

From the Section of Neuroradiology Department of Diagnostic Radiology University Hospital S-221 85 Lund Sweden Submitted for publication 8 January 1979

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Tomas Hindmarsh

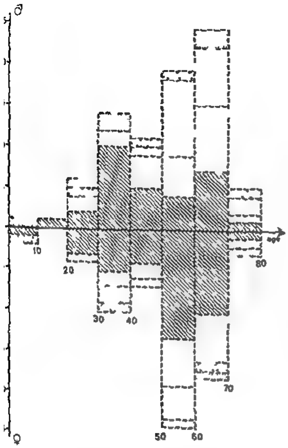

Fig 2 149 patients with acute subarachnoid hemorrhage and a clinical history compatible with the rupture of an intracranial arterial aneurysm Age and sex distribution of material divided into final diagnoses aneurysm hemorrhage no etiology cerebral hemorrhage arteriovenous malformation mixed

subarachnoid hemorrhage could obviate the need for or limit the extent of a subsequent angiography The undisputed value of computer tomography for the later management of the patients with respect to the deveolpment of ischemia infarcts repeat ble dings hydrocephalus and postoperative complications will not be discussed neither will the therapeutic implications of a disclosure of an intraventricular hemorrhage

Material and Methods

Of a total of 3 250 CT examinations performed at this hospital from March 1977 to October 1978 149 were performed on patients with confirmed acute subarachnoid hemorrhage and a clinical history consistent with the rupture of an intracranial arterial aneurysm CT was routinely performed on the day of admission as the primary radiologic procedure In a few cases predominantly early in the series CT was for technical reasons not performed until after angiography in single cases after

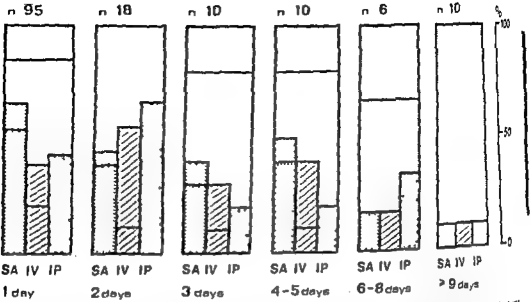

Fig 1 CT findings in 149 patients examined for acute subarachnoid hemorrhage in relation to time interval between bleeding and CT Left column 1 day denotes examination performed within the day after the hemorrhage n = number of patients in each group SA IV and IP denote blood in the subarachnoid intraventricular and intraparenchymatous spaces respectively For SA a d IV lower darker part indicates much blood upper lighter part small amount of blood Dark upper area denotes fraction of examinations without abnormality

Table 1

Extent of angiography both for the entire material and for those cases examined with CT within 2 days after subarachnoid hemorrhage divided into categories of final diagnosis Figures within parentheses denote number of examinations where a bilateral carotid examination was obtained by unilateral injections and contralateral carotid compression

	Bilateral carotid angiography			Unilateral carotid angiography		No angiography	Total
	Bilat vert	Unilat vert	No vert	Unilat vert	No vert		
Subarachnoid hemorrhage — no etiology							
CT ≤ 2d	13	6	5 (1)	—	—	2	26
Total	21 (1)	9 (1)	7 (1)	—	—	2	39
Aneurysm							
CT ≤ 2d	15	10 (1)	19 (6)	—	6	3	53
Total	18	15 (1)	23 (6)	—	8	3	67
Cerebral hemorrhage							
CT ≤ 2d	3 (1)	—	2 (2)	1	6	10	22
Total	4 (1)	—	4 (3)	1	6	12	27
Arteriovenous malformations							
CT ≤ 2d	—	3	2 (2)	1	1	—	7
Total	—	4	2 (2)	1	1	—	8

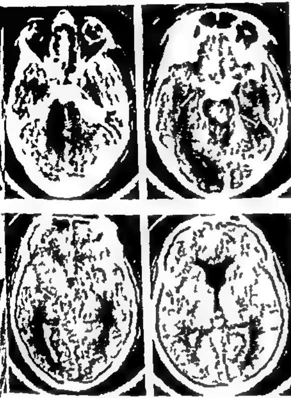

Fig 6 Patient with acute subarachnoid hemorrhage Much subarachnoid blood (+ →) in the suprasellar (→) ambient (↠) and pontine (⇻) cisterns as well as in the Sylvian (⇸) and interhemispheric (⤚) fissures Also hemorrhage in the brainstem and blood in the lateral ventricles

artery 23 of the anterior communicating artery 3 of the basilar artery one of the posterior inferior cerebellar artery and 5 of other locations Primary intracerebral hemorrhage was found in 27 patients arteriovenous malformation in 8 brain tumor in 4 (one probable) trauma in 3 and probable infarct in one patient In 39 cases no etiology for the hemorrhage could be demonstrated The age and sex distribution of the entire material split into the different diagnostic categories is presented in Fig 2 If no etiology was found in spite of bilateral carotid and uni or bilateral vertebral angiography the case was classified as hemorrhage—no etiology If a less extensive angiographic examination had been performed the cases were registered as incomplete examinations

For each diagnostic category the CT examinations were evaluated with respect to the demonstration of an intraparenchymatous (Fig 3) or an intraventricular (Figs 4 5) hemorrhage as well as to the presence and distribution of blood in the subarachnoid space (Figs 6 7) For the subarachnoid and intraventricular spaces the amount of blood was classified as + + (much blood) or + (small amount of blood) Blood was considered to be present in the cisterns only when these had attenuation values well above those in the surrounding brain tissue

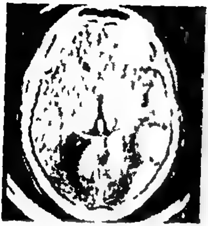

Fig 3

Fig 4

Fig 3 Leftsided superficial parieto-occipital intraparenchymatous hemorrhage clinically presenting as acute subarachnoid hemorrhage

Fig 4 Patient with acute subarachnoid hemorrhage Much blood (+ +) in the ventricular system

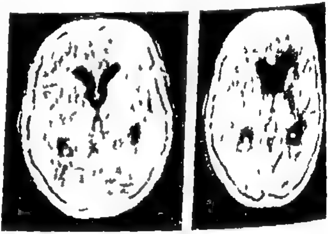

Fig 5 Patient with acute subarachnoid hemorrhage Small amount of blood (+) in the occipital horns (⟶)

an interval of several days The interval between the hemorrhage and the CT examination appears in Fig 1 All CT examinations were performed on an EMI 1010 head scanner using 10 mm slice thickness normal accuracy and definition mode and 240 revolution Intravenous contrast medium was given only in a few patients on special indications i e findings on the not enhanced scan suggesting the presence of a tumor or an arteriovenous malformation

Routine techniques were used for angiography The angiography was in many cases planned and restricted with consideration to the findings at CT The extent of the angiography for the different categories of final diagnosis is given in Table 1

The total information available from the history CT examination, angiography and, in some cases also surgery or autopsy was used to establish the final diagnosis In 67 patients 90 aneurysms were found one aneurysm in 51 2 in 12 and more than 2 aneurysms in 4 patients The location of the aneurysms was as follows 33 of the internal carotid—posterior communicating artery 25 of the middle cerebral

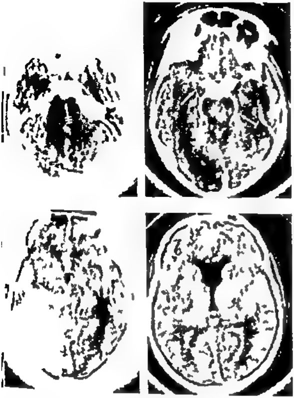

Fig 6 Patient with acute subarachnoid hemorrhage Much subarachnoid blood (+ +) in the suprasellar (→) ambient (↠) and pontine (⇻) cisterns as well as in the Sylvian (⇸) and inter hemispheric (↣) fissures Also hemorrhage in the brainstem and blood in the lateral ventricles

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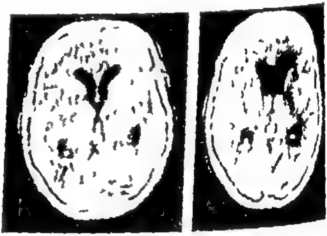

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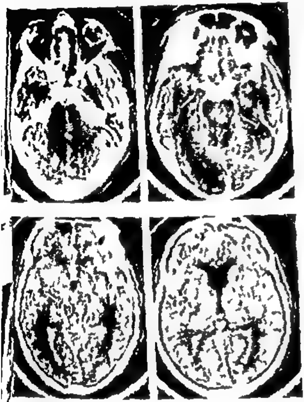

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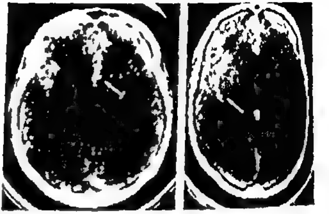

Fig 7 Patient with acute subarachnoid hemorrhage Small amount of blood (→) in the right Sylvian (→) and in the interhemispheric (↔) fissures

Results

The correlation between the presence and amount of demonstrable blood in the different compartments and the final diagnosis is presented in Table 2

The percentage of positive findings in relation to the time lapse between the hemorrhage and the CT examination appears in Fig 1 The percentage of positive findings was highest during the first 2 days following the bleeding (day of bleeding = day 0) and thereafter successively decreased Only one of 10 examinations performed more than 8 days after the hemorrhage was positive—a small amount of blood was demonstrated in one of the lateral ventricles on the twelfth day However the possibility of a repeat bleeding cannot be excluded in this case

In order to evaluate the diagnostic value of a CT examination performed in the acute stage of subarachnoid hemorrhage patients with a CT examination performed during the first 2 days following the hemorrhage were analysed separately The material thus reduced amounted to 113 patients 53 aneurysms 7 arteriovenous malformations 22 intracerebral hemorrhages 3 tumors 2 trauma cases 19 subarachnoid hemorrhages—no etiology and 7 cases classified as incomplete examination The percentage of negative examinations as well as the frequency of intraparenchymatous intraventricular and subarachnoid hemorrhage for the different groups of final diagnosis is given in Fig [illegible] Blood in the subarachnoid space was observed in more than 90 per cent of the aneurysm group in about half of the cases with arteriovenous malformations or hemorrhage—no etiology and in one fourth of the cases with intracerebral hemorrhage Intraventricular hemorrhage was demonstrated in two thirds of the arteriovenous malformations and intracerebral hemorrhages in one third of the aneurysms and hemorrhage—no etiology cases. Furthermore the patients in the first two groups often had much blood in the ventricles patients in the latter two groups usually only a small amount Intraparenchymatous hemorrhage was found in 40 per cent of the aneurysm cases and in 6 of 7 malformations The CT examinations was considered normal in one third of the patients in the hemorrhage—no etiology group in one of 7 in the malformations and

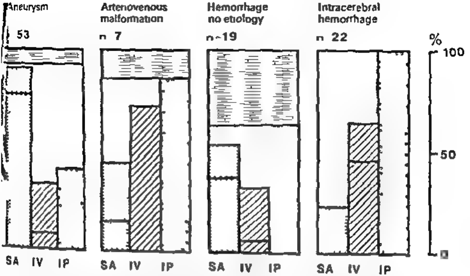

Fig 8 CT findings for each diagnostic category All CT examinations performed with 2 days after the subarachnoid hemorrhage All patients classified as subarachnoid hemorrhage no etiology found at vertebral and bilateral carotid angiography n = number of patients in each group SA IV and IP denote blood in the subarachnoid intraventricular and intraparenchymatous spaces respectively For SA and IV lower darker part indicates much blood upper lighter part small amount of blood Dark upper area denotes fraction of examinations without abnormality

in 8 per cent of the aneurysm group (4 cases 1 anterior and 3 posterior communicating artery aneurysms)

The correlation between the lateralization of intraparenchymatous bleeding and blood in the subarachnoid space and the location of the ruptured aneurysm for all 53 aneurysm cases that were examined within 2 days after the bleeding is presented in Table 3 In all 12 cases with a ruptured middle cerebral artery aneurysm the side of the hemorrhage was indicated by the CT while in 7 of 20 cases with a posterior communicating artery aneurysm CT was non informative and in one case even misleading In 9 of 15 cases with an anterior communicating artery aneurysm the same amount of blood was found on both sides in 5 cases more blood on one side Totally of 17 patients with a ruptured midline aneurysm 11 had symmetric and 5 asymmetric distribution of the blood the corresponding figures for 36 lateral aneurysms were 4 and 29 respectively (of these one case had most blood on the healthy side)

The detailed distribution of blood in the subarachnoid space and the presence of intraventricular and intraparenchymatous blood in relation to location of the aneurysm appear in Table 4 The distribution of blood in all cases with a ruptured middle cerebral artery aneurysm had the same appearance much blood in the ipsilateral Sylvian fissure (Fig 9) often also an intraparenchymatous hematoma The distribution of blood was usually evidently asymmetric and in most cases no

Table 2

Distribution of extravasated blood at CT correlated to final diagnosis in 149 patients with subarachnoid hemorrhage and clinically possible ruptured intracranial aneurysm s p f = single pa hol fos + + = much blood No etiology = no explanation for hemorrhage inspite of vertebral and b carotid angiographies Incomplete = less extensive evaluation performed

Blood	Cerebral hemorrhage	Aneurysm	Arteriovenous malformation	Subarachnoid hemorrhage: No etiology	Subarachnoid hemorrhage: Incomplete	Trauma	Tumor	Total
Intraparenchymatous	27	21	6	—	1	2	[illegible]	59
Intraparenchymatous s p f	10	—	—	—	—	1	—	11
Intraventricular	16	21	5	7	5	—	[illegible]	56
Intraventricular + +	12	4	5	1	2	—	1	25
Intraventricular s p f	—	2	—	2	2	—	—	6
Intraventricular + + s p f	—	—	—	1	1	—	—	[illegible]
Subarachnoid space	5	54	3	14	5	—	—	81
Subarachnoid space + +	5	46	1	10	4	—	—	66
Subarachnoid space s p f	—	23	—	10	1	—	—	34
Subarachnoid space + + s p f	—	16	—	8	1	—	—	25

Table 3

Correlation between aneurysm location and lateralisation features of CT examinations in 53 patients examined with CT within 2 days after acute subarachnoid hemorrhage

	Ant com artery	Post com artery	Middle cerebral	Basilar artery	Other locations	Total
Hematoma localising aneurysm	4	5	8	0	4	21
More blood on side of aneurysm	—	7	4	—	0	11
Symmetric distribution of blood	5	4	0	2	0	11
Asymmetric distribution of blood midline aneurysm	5	—	—	0	—	5
More blood on healthy side	—	1	0	—	0	1
No abnormality	1	3	0	0	0	4

blood or only a small amount appeared in the ambient cisterns In the group of anterior communicating artery aneurysms most blood was found in the interhemispheric fissure relatively much blood in the Sylvian fissure and little if any blood in the ambient cisterns (Fig 10) In patients with a ruptured posterior communicatin

Table 4

Distribution of blood at CT 0 to 2 days after subarachnoid hemorrhage correlated to location of aneurysm + = small amount of blood + + = much blood ! = more blood than on contralateral side

Supra sellar	Sylvian fissure Ipsilat	Sylvian fissure Contralat	Ambient cistern Ipsilat	Ambient cistern Contralat	Interhem fissure	Intra ventr	Intra parench
Posterior communicating artery							
+	+ +	+	+ +	+ +	+	+	
+ +	+ + !	+ +	+ +	+	+		
+	+ + !	+ +	+ +	+ +	+ +	+ +	+
			+ +	+ +			
	+ +	+	+	+			+
	+ +	+ +	+ +	+ +	+ +		
	+ +	+ +	+ +	+ +	+ +	+ +	
	+ + !	+ +	+ +	+ +	+ +		+
	+ +	+			+		
+	+ +	+ +	+ +	+ +	+ +	+	+
	+ +	+ +	+ +	+ + !			
					+		
	+ +	+	+	+	+		
	+ +	+	+ +	+	+ +		
			+	+		+	
+	+ +	+ +	+	+	+	+	+
Anterior communicating artery							
	+	+	+	+	+ +		+
					+		
+					+ +		+
	+ +	+	+	+		+	
+	+ +	+	+ +	+	+		
+	+	+	+	+	+ +		
+	+	+ +			+ +	+	+
					+ +		
+ +					+ +	+	+
	+ +	+	+ +	+ +	+ +	+	
	+ +	+ +			+ +		
					+		
	+	+					
+	+ +	+	+	+	+ +	+	
Middle cerebral artery							
+ +	+ +	+	+		+	+	
	+ +						+
	+ +						+
+	+ +	+					+
	+ +	+	+	+	+		+
					+	+	

Table 4 (*cont*)

Supra sellar	Sylvian fissure		Ambient cistern		Interhem fissure	Intra ventr	Intra parench.
	Ipsilat	Contralat	Ipsilat	Contralat			
++	++	++	++	++	++		-
++	++!	++					+
+	++	+	+		+		-
++	++			+	+	+	
	++	+	+		+		+
	++		+		+		
+	++!	++	++	+	+	+	

artery aneurysm, blood was usually more evenly distributed in the basal cisterns (Fig 11) Blood in the ambient cisterns was a much more common finding in this group than for other aneurysm locations In most cases no evident lateralization of the blood in the group with posterior communicating artery aneurysms was found in contrast to the findings with middle cerebral artery aneurysms

Discussion

Subarachnoid hemorrhage i e presence of blood in the cerebrospinal fluid is a non specific finding that may be caused by a variety of lesions Ruptured aneurysms trauma spontaneous intracerebral hemorrhages arteriovenous malformations and malignant tumors are common causes The 'physician s task is to assess the likelihood that the cause of the hemorrhage is a remedial lesion and, therefore the need for intracranial investigations (Editorial Brit med J 1978) Previously the clinician has been forced to make this assessment solely on the basis of clinical history and clinical findings in a few cases supplemented with information midline shift from skull films or ultrasound The introduction of CT has provided the physician with a much more potent diagnostic tool permitting the direct demonstration of infarcts and tumors, intraparenchymatous and intraventricular hemorrhages and even blood in the subarachnoid space In this department CT disclosed 3 cases with post traumatic abnormalities one infarct and 4 tumor cases (1 equivocal) among 149 patients with clinical suggestion of a ruptured intracranial aneurysm.

In establishing the cause of a subarachnoid hemorrhage it is often difficult to differentiate between a primary intracerebral hemorrhage and an aneurysmal rupture particularly when the latter is associated with an intracerebral hematoma This differentiation can now be made with high accuracy from the CT findings

HAYWARD & O REILLY (1976) reported 90 per cent correct diagnosis when using the location and appearance at CT in predicting the underlying pathology in 100 cases with non traumatic intracerebral hematoma The identificiation of spontaneous

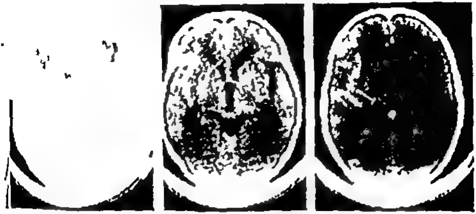

Fig. 9 Subarachnoid hemorrhage after rupture of a rightsided middle cerebral artery aneurysm Much blood (+ −) in the suprasellar cisterns (→) and the ipsilateral Sylvian fissure (↦) Small amount (−) in the contralateral ambient cistern (↠) and the interhemispheric fissure (⤚)

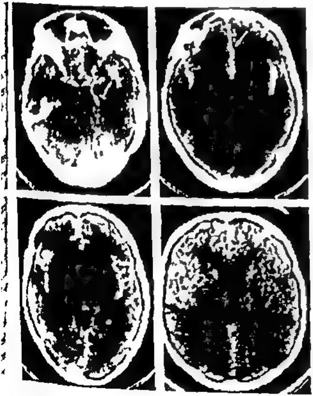

Fig 10 Subarachnoid hemorrhage following rupture of an anterior communicating artery aneurysm Much blood (+ +) in the interhemispheric (→) and both Sylvian fissures (↦)

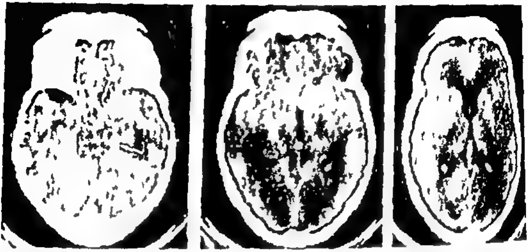

Fig 11 Subarachnoid hemorrhage following rupture of a posterior communicating artery aneurysm Small amount of blood (+) in the suprasellar (↔) and both ambient cisterns (→)

hemorrhage was successful also in the present material As evident from Table 5 an intraparenchymatous hemorrhage if not associated with a demonstrable hemorrhage in the subarachnoid space constituted a primary hemorrhage in 17 of 21 cases and in only one case was it due to a ruptured aneurysm On the other hand an intraparenchymatous hemorrhage, when associated with demonstrable hemorrhage in the subarachnoid space in 20 of 29 cases was caused by an aneurysm rupture and in only 5 cases constituted a primary hemorrhage Four of the latter 5 cases had the typical CT appearance of a central spontaneous intracerebral hemorrhage the fifth was a hemorrhage in the brain stem (Fig 6) The capability of CT to identify tumors, trauma and spontaneous hemorrhages—a group amounting to 34 of 149 cases in the present material—and in a majority of these cases to obviate the need for extensive angiography is probably sufficient to economically motivate the routine use of CT as the primary examination in cases with subarachnoid hemorrhage

However this is not the only capability of CT in the evaluation of subarachnoid hemorrhage In cases with a ruptured intracranial aneurysm CT often indicates the side of the lesion by demonstrating an intracerebral hematoma or an uneven distribution of the blood in the subarachnoid space KENDALL et coll found lateralising features in 86 per cent of their aneurysm cases when CT was performed within 7 days after the bleeding SCOTTI et coll found blood in the subarachnoid space in all 42 patients examined within 7 days of the bleeding and predicted that CT would prove to be reliable in 100 per cent and obviate the need for lumbar puncture provided the examination was performed within 5 to 7 days after the bleeding On the other hand ALMAANI & RICHARDSON though able to locate the aneurysm in all their cases with an abnormal CT scan could demonstrate blood in the subarachnoid space in only 29 of 58 patients and therefore assessed the technique as of limited value However they did not report the time interval between the bleeding

Table 5

ompartmental distribution of blood in relation to final diagnosis in 113 patients examined with CT ithin 2 days after subarachnoid hemorrhage No etiology group consists of patients examined with ertebral as well as carotid angiography Incomplete group consists of patients subjected to less extensive angiographic examination and no explanation of hemorrhage

	Total	Aneurysm	Arterio-venous malformation	Subarachnoid hemorrhage		Cerebral hemorrhage
				No etiology	Incomplete	
umor trauma infarction	5					
ntraparenchymatous blood in some also subarachnoid or intraventricular	50					
Also subarachnoid blood	29	20	3	0	1	5
No subarachnoid blood	21	1	3	0	0	17
No intraparenchymatous blood subarachnoid blood possibly also intraventricular	42					
More blood on one side	21	17	0	3	1	0
Symmetric distribution	21	11	0	7	3	0
Only intraventricular blood	3	–	0	2	1	0
Normal examination	13	4	1	7	1	0

and the CT As evident from the present material (Fig 1) as well as from other reports (LILIEQUIST et coll SCOTTI et coll KENDALL et coll) blood in the subarachnoid space is demonstrated with a high frequency only during the first few days following the bleeding

The capability of CT to locate the ruptured aneurysm is of main significance in cases with multiple aneurysms where difficulties in identifying the aneurysm responsible for the bleeding sometimes occur KENDALL et coll reported absence of definite angiographic localizing features in 43 per cent of their cases

The value of starting the angiographic examinations with the proper vessel is dependent on the surgical policy regarding multiple aneurysms If in order to eliminate the risk of future hemorrhages (HEISKANEN & MARTTILA 1970) also incidental aneurysms are operated upon complete four vessel examination must be performed in any case and the value is limited However KENDALL et coll after reviewing the literature and analysing a personal material of 100 cases with multiple aneurysms concluded that the incidence of hemorrhage from incidental aneurysms is sufficiently low to justify not interfering with the majority of them and therefore to limit angiography to that necessary for proper treatment of the recently ruptured aneurysms If this policy is accepted large savings will be gained by using CT as the *primary* examination in cases with subarachnoid hemorrhage In the present material (Table 3) an angiography starting with the carotid artery on the side with most blood would catch the feeding vessel of a lateralised

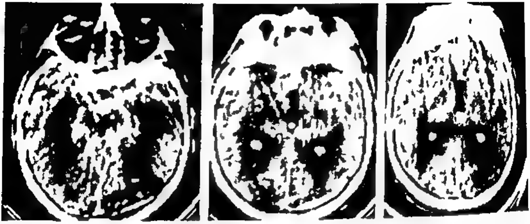

Fig 12 Subarachnoid hemorrhage following rupture of rightsided posterior communicating artery aneurysm Much blood (+ →) in both Sylvian fissures in the suprasellar and both ambient cisterns. In spite of rightsided location of aneurysm most blood in the left ambient cistern

aneurysm in 28 of 34 cases in 5 cases would be adequate for the demonstration of a midline aneurysm and in only one case would be performed in the wrong vessel Among 15 cases with a symmetric distribution of blood any carotid artery would be adequate in 9 cases with an anterior communicating artery aneurysm (4 of which were clearly indicated through a localized hematoma) while in the remaining 6 cases as well as in 4 cases with no abnormality at CT this examination would not contribute to the evaluation

A related question is whether or not to pursue a complete four vessel angiography if CT clearly lateralises the lesion and no abnormality is found at a proper carotid angiography In none of the cases in the material of KENDALL et coll in which a source of the hemorrhage had not been found near the CT abnormality did a complete angiography demonstrate a relevant lesion elsewhere On the other hand in one patient (Fig 12) in the present material more blood was observed in the subarachnoid space on the normal side than on the side of the aneurysm At present a wise philosophy would probably be when no abnormality is found at carotid angiography on the side of the CT abnormality to avoid a complete four vessel angiography only in cases with clearly located hematoma at CT in cases with temporal lobe hematomas only provided the posterior communicating artery is well depicted

An additional value of CT is gained in cases where angiography using the routine aneurysm projections is primarily considered to be without abnormality In such cases a blood distribution at CT clearly localising the lesion should motivate a re evaluation of the films if necessary supplementary projections and probably also a repeat angiography This statement is valid particularly for aneurysms of the middle cerebral and anterior communicating artery where a good correlation between the location of the aneurysm and the CT is to be expected (Table 4 SCOTT et coll)

Conclusion

Based on the experience from a material of 149 patients with acute subarachnoid hemorrhage and a clinical history consitent with the rupture of an intracranial arterial aneurysm it is concluded that CT is motivated as the primary examination in the evaluation of acute subarachnoid hemorrhage because

(1) Cases with disorders such as malignant tumors traumatic injuries or primary intracerebral hemorrhages (totally 43 cases) were identified and the subsequent angiography could be limited or even obviated

(2) When performed within the first few days CT usually indicated the side and even site of the ruptured aneurysm If the surgical policy of only operating upon ruptured aneurysms and not upon incidental ones is accepted the angiography could thus start with and be restricted to what is needed for an evaluation of the ruptured aneurysm

(3) In cases where CT clearly indicates a focal lesion but angiography of the proper vessel is normal there may be indications for a repeat angiography

SUMMARY

CT was performed in 149 patients with acute subarachnoid hemorrhage and clinical findings consistent with an aneurysm rupture and was found informative in most cases when performed within one week after the hemorrhage CT disclosed in 29 per cent of cases other causes for the hemorrhage than a ruptured aneurysm (intracerebral hemorrhage tumor trauma infarct) and an extensive angiographic evaluation could be omitted In those patients where the hemorrhage was caused by an aneurysm rupture the distribution of extravasated blood in the subarachnoid space and the brain parenchyma usually indicated the aneurysm location—angiography could thus be restricted to the proper vessel These capabilities of CT are sufficient to economically motivate its routine use as the primary investigation in cases with an acute subarachnoid hemorrhage

ZUSAMMENFASSUNG

Computertomographie welche bei 149 Patienten mit akuter subarachnoidaler Blutung und klinischen Befunden die mit einer Ruptur eines Aneurysmas uberenstimmen durchgefuhrt wurde war in den meisten Fallen informativ wenn diese innerhalb einer Woche nach der Blutung vorgenommen wurde CT offenbarte in 29 Prozent der Falle andere Ursachen fur die Blutung als eine Ruptur eines Aneurysmas (intrazerebrale Blutung Tumor Trauma Infarkt) und eine umfassende angiographische Untersuchung konnte vermieden werden Bei denjenigen Patienten bei denen die Blutung durch eine Ruptur eines Aneurysmas verursacht war indikierte die Verteilung des extravasierten Blutes in dem Subarchnoidalraum und dem Gehirnparenchym gewohnlich die Lokalisation des Aneurysmas—eine Angiographie konnte dadurch auf das entsprechende Gefass eingeschrenkt werden Diese Eigenschaften der CT genugen um CT okonomisch fur die Routine Anwendung als primare Untersuchungsmethode bei Fallen mit einer akuten subarachnoidalen Blutung zu motivieren

RÉSUME

Une tomodensitométrie a été pratiquée chez 149 malades atteints d hémorragie sousara h noïdienne aiguë et ayant des signes cliniques évoquant une rupture d anévrisme elle a é e utile dans la plupart des cas quand elle est effectuée dans la semaine qui suit l hémorra ·e La TDM a révelé dans 29 pour cent des cas une cause d hémorragie autre qu une rup ure d anévrisme (hémorragie intracérebrale tumeur traumatisme ramollissement) et a permis d éviter un examen angiographique étendu Chez les malades dont l hémorragie est causée par une rupture d anévrisme la répartition du sang extravase dans l espace sous arachnoïdien et dans le parenchyme cérébral a en général indiqué la situation de l anévrisme l angiographie a ainsi pu etre limitée au vaisseau en cause Ces possibilités de la TDM suffisent a justifier économiquement son utilisation courante comme premier moyen d examen dans les cas d hémorragie sous arachnoidienne aiguë

REFERENCES

ALMAANI W S and RICHARDSON A E Multiple intracranial aneurysms Identifyin the ruptured lesion Surg Neurol 9 (1978) 303

BAHR A L and HODGES F J Efficacy of computed tomography of the head in changing patient care and health costs A retrospective study Amer J Roentgenol 131 (1978) 45

DAVIS K R NEW P F J OJEMANN R G CROWELL R M MORAWETZ R B and ROBERSON G H Computed tomographic evaluation of hemorrhage secondary to intracranial aneurysm Amer J Roentgenol 127 (1976) 143

EDITORIAL Subarachnoid haemorrhage of unknown cause Brit med J 1 (1978) 373

HAYWARD R D Subarachnoid haemorrhage of unknown aetiology A clinical and radiological study of 51 cases J Neurol Neurosurg Psychiat 40 (1977) 926

— and O REILLY G V A Intracerebral haemorrhage Accuracy of computerized transverse axial scanning in predicting the underlying aetiology Lancet 1 (1976) 1

HEINZ E E *In* Complications and legal implications of radiologic special procedures, p 55 Edited by T E Meaney A F Lalli and R J Alfidi C V Mosby St Louis 1973

HEISKANEN O and MARTTILA I Risk of rupture of a second aneurysm in patients with multiple aneurysms J Neurosurg 32 (1970) 295

KENDALL B E LEE B C P and CLAVERIA E Computerized tomography and angiography in subarachnoid haemorrhage Brit J Radiol 49 (1976) 483

LARSON E B OMENN G S and LOOP J W Computed tomography in patients with cerebrovascular disease Impact of a new technology on patient care Amer J Roentgenol 131 (1978) 35

LILIEQUIST B LINDQVIST M and VALDIMARSSON E Computed tomography and subarachnoid hemorrhage Neuroradiology 14 (1977) 21

LIM S T and SAGE D J Detection of subarachnoid blood clot and other thin flat structures by computed tomography Radiology 123 (1977) 79

LITTLE J R BLOMQUIST G A JR and ETHIER R Intraventricular hemorrhage in adults Surg Neurol 8 (1977) 143

PRESSMAN B D KIRKWOOD J R and DAVIS D O Computerized transverse tomography of vascular lesions of the brain Part I Arteriovenous malformations Amer J Roentgenol 124 (1975) 208

SCOTTI G ETHIER R MELANCON D TERBRUGGE K and TCHANG S Computed tomography in the evaluation of intracranial aneurysms and subarachnoid hemorrha e Radiology 123 (1977) 85

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PORTO SYSTEMIC COLLATERALS IN CIRRHOSIS OF THE LIVER

Selective percutaneous transhepatic catheterization of the portal venous system in portal hypertension

J HOEVELS A LUNDERQUIST U TYLEN and G SIMERT

In upper gastrointestinal bleeding in patients with cirrhosis of the liver portal hypertension and gastroesophageal varices a new therapeutic method was obtained when LUNDERQUIST & VANG (1974) applied the percutaneous transhepatic access to the portal venous system for occlusion of porto-systemic collaterals feeding esophageal varices Before this treatment is applied a thorough demonstration of all collateral veins to the distal segment of the esophagus is mandatory Percutaneous transhepatic portography and selective catheterization of the major splanchnic veins can provide this essential morphologic and hemodynamic information The various porto-systemic communications and their correlation to the prevailing portal venous pressure and direction of blood flow in the main stem of the portal vein are reported in the present communication

Material and Methods

The series comprised 93 patients (62 males 31 females) ranging from 16 to 90 years of age (mean 58 years) The material included the majority of the patients whose clinical and portographic findings were correlated in a recent investigation

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(SIMERT et coll 1978) Cases were excluded in which specific treatment of portal hypertension such as surgical shunts or sclerosing injections had been carried out. Needle biopsy or post mortem examination confirmed the diagnosis of cirrhosis of the liver in 65 cases whereas in 28 cases the diagnosis was based on clinical and laboratory findings only In 3 cirrhotic livers a primary malignant tumor was found

Demonstration of portal vein patency by arterial portography is necessary before percutaneous transhepatic portography is carried out, which was performed with the patient supine Following premedication (10 mg diazepam and 0 5 mg atropine intramuscularly) and local anesthesia of the subcutis and intercostal tissue, a 15 cm long stylet in a polyethylene catheter (OD/ID 1 6/1 0 mm) under fluoroscopy was inserted from the right midaxillary line towards the area directly cranial to the approximate position of the liver hilum After removal of the stylet the catheter was slowly withdrawn until blood could be aspirated Following identification of a branch from the portal vein by injection of contrast medium a guide wire was introduced through the catheter and manipulated into the main stem of the portal vein The catheter was then pushed over the guide wire into the main stem of the portal vein and the guide wire removed The technique of percutaneous transhepatic puncture and catheterization of the portal vein has been described in more detail by HOEVELS et coll (1978)

Complete evaluation of hepatofugal venous blood flow towards the veins of the distal segment of the esophagus requires selective injection into the splenic vein as close as possible to the hilum of the spleen and in the main stem of the superior mesenteric vein

In 76 cases contrast medium was injected into both the splenic vein and the superior mesenteric vein whereas in 17 cases only the splenic vein was catheterized selectively The catheter was placed in these positions by the guide wire technique Pressure recordings were performed in all cases by connecting an open manometer to the catheter The midaxillary line was chosen as reference point corresponding approximately to the level of the portal vein The portohepatic pressure gradient i e free portal venous pressure minus free hepatic venous pressure, was not determined

The findings at percutaneous transhepatic portography were evaluated and classified according to the following criteria

(1) Pressure in the main stem of the portal vein and its relation to the diameter of the portal vein at its midpoint i e halfway between the spleno mesenteric junction and the bifurcation of the main stem of the portal vein No correction was made for the magnification on the film (approximately 33 %)

(2) Portal venous pressure related to the direction of blood flow (hepatopetal hepatofugal) in the main stem of the portal vein

(3) Portal venous pressure related to the degree and appearance of porto systemic collateral flow in the total material

(4) Portal venous pressure related to the absence or presence of esophageal varices

Table 1

Porto-systemic collaterals in 93 cases

Left gastric vein	[illegible]	Left inferior phrenic vein	[illegible]
Short gastric veins	54	Splenorenal gastrorenal collaterals	24
Esophageal veins (varices)	82	Para umbilical vein	27
Para-esophageal veins	27	Inferior mesenteric vein	55
Upper splenic hilum veins	11	Colon veins	22
Lower splenic hilum veins	24	Retroperitoneal veins	[illegible]
Right intercostal veins	3	Inferior epigastric veins	8
Left intercostal veins	21	Posterior superior pancreatico-duodenal vein	25
Right/left diaphragm veins	8	Anterior superior pancreatico-duodenal vein	11
Mediastinal veins	15	Azygos/hemiazygos veins	18

(5) Grading of the extent of esophageal varices arbitrarily according to degrees 0-1-2-3

(6) Flow of contrast medium to esophageal varices and para esophageal veins via the left gastric vein only the short gastric veins only and both left gastric and short gastric veins

(7) Portal venous pressure related to the diameter of the left gastric vein measured 0.5 cm proximal to its junction with the portal or splenic vein No correction was made for the magnification on the film

(8) Porto systemic collateral flow in cases without esophageal varices according to the findings at portography

Results

(1) The mean value for portal venous pressure in the total material was 35 cm H_2O (range 20–60) The diameter of the main stem of the portal vein was 18 mm (range 8–40) No correlation was found between the portal venous pressure and the diameter of the main stem of the portal vein

(2) The mean value for portal venous pressure when hepatopetal flow in the main stem of the portal vein was present (78/93 cases) was 33 cm H_2O (range 20–50) and when hepatofugal flow in the main stem of the portal vein was present (15/93 cases) 38 cm H_2O (range 28–50) A marginal difference between the means of these two groups was found However no correlation existed between the portal venous pressure and the direction of flow in the main stem of the portal vein in the individual case

(3) No correlation was found between the portal venous pressure and the extent and appearance of porto-systemic collaterals

Hepatofugal blood flow via porto-systemic communications was demonstrated in abdominal retroperitoneal and thoracic veins A detailed survey of the porto-systemic collaterals which could be identified is given in Table 1 In 12 cases the main collateral flow occurred via the left gastric vein only in 31 cases via the left gastric

Table 2

Porto systemic collaterals in 11 cases without esophageal varices

Para umbilical vein	6	Short gastric veins	3
Left gastric vein	5	Intercostal veins	3
Inferior mesenteric vein	6	Lower splenic hilum vein	1
Splenorenal collateral	1	Posterior superior pancreatico-duodenal vein	1

vein and one major collateral in 22 cases via the left gastric vein and 2 major collaterals and in 15 patients via the left gastric vein and 3 major collaterals In 13 cases the main collateral flow occurred via major collateral veins without engagement of the left gastric vein

The left gastric vein was classified as a large collateral (>10 mm) in 2? cases a para umbilical vein (>8 mm) in 9 cases and the inferior mesenteric vein (~8 mm) in 27 cases A splenorenal collateral was classified as a large porto systemic communication (>6 mm) in 7 cases

Extremely large porto systemic collaterals were present in single cases The portal venous pressure ranged between 22 and 30 cm H O in these No case was found in which porto systemic collateral flow resulted in reduction of the portal venous pressure to normal value

(4) The mean value for portal venous pressure when esophageal varices were absent (other porto systemic collaterals present) was 31 cm H O (range 20–36) and when esophageal varices and other porto systemic collaterals were present 35 cm H O (range 22–50) A marginal difference between the means of these two groups was found but no correlation between the portal venous pressure and the absence or presence of esophageal varices

(5) The esophageal varices were classified as small in 25 cases medium in 35 cases and large in 22 cases No varices were demonstrated in 11 cases but selective examination of the left gastric vein was not performed in 5 of these No correlation was found between the degree of esophageal varices and the portal venous pressure

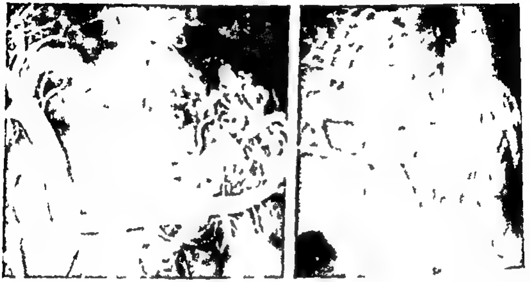
(6) Hepatofugal blood flow to the esophageal and para esophageal veins occurred via the left gastric vein in 32 cases and via both the left gastric vein and short gastric veins in 43 cases In 7 cases the veins of the distal segment of the esophagus were filled via short gastric veins only

(7) Hepatofugal blood flow through the left gastric vein was demonstrated in 80/93 cases In 75 cases the flow was directed to esophageal and para esophageal veins whereas the blood was drained to the inferior vena cava via a gastrorenal shunt in 5 cases The mean diameter of the vein was 8 mm (range 3–14) No correlation was found between the portal venous pressure and the diameter of the left gastric vein

(8) The porto systemic collaterals in 11 cases without esophageal varices are listed in Table 2

Fig 1 73 year-old male with carcinoid tumor of the ileum Selective percutaneous trans hepatic catheterization and in jection of contrast medium into inferior mesenteric vein Con nection with inferior vena cava (↔) via small retroperitoneal vein (→) Portal venous pres sure within normal limits (12 cm H O)

Fig 2 66-year-old male with cirrhosis of the liver Portal venous pressure within normal limits (12 cm H O) Porto-systemic flow from intrahepatic portal vein branch (→) to mediastinal vein



a b

Fig. 3. 67 year old male with cirrhosis of the liver and portal hypertension. Portal venous pressure 37 cm H_2O (uncorrected value). (From Fortschr. Röntgenstr. 128 (1978) 437 with the permission of Thieme Verlag, Stuttgart.) a) Selective injection of contrast medium into splenic vein. Partial drainage through short gastric and capsule veins of the spleen to spontaneous splenorenal shunt (→). Left gastric vein and esophageal varices not demonstrated. b) Selective injection of contrast medium into superior mesenteric vein. Hepatofugal flow through left gastric vein to esophageal varices. Para umbilical vein in ligamentum falciforme hepatis.

Discussion

The selective access to the main tributaries of the portal vein, i.e. the splenic, left gastric, superior and inferior mesenteric veins, makes percutaneous transhepatic portography an ideal complement to celiac, superior mesenteric, and left gastric angiography for the evaluation of hemodynamics in patients with cirrhosis of the liver and increased pressure in the portal venous system. In addition to pressure recordings and hemodynamic analyses in different parts of the portal and splanchnic veins, it makes possible transcatheter occlusion of veins draining blood to esophageal varices (LUNDERQUIST & VANG; LUNDERQUIST et coll. 1977, 1978; DOYON et coll. 1975; GÜNTHER et coll. 1976, 1977; SCOTT et coll. 1976; COOPERMAN & ALFIDI 1976; DEIMER et coll. 1978; PEREIRAS et coll. 1977, WIDRICH et coll. 1978; KELLER et coll. 1978). On the other hand, percutaneous transhepatic portography is of no value for diagnosis of the bleeding source in patients with portal venous hypertension and gastrointestinal hemorrhage. Despite selective injection of contrast medium in left and short gastric veins during profound hematemesis in 16 of the present patients with endoscopically confirmed esophageal varices, extravasation of contrast medium could not be demonstrated.

RETZIUS (1835), THAMM (1940) and EDWARDS (1951) have demonstrated an abundance of normally patent porto systemic communications in the pelvis, across the retroperitoneal surfaces of the abdominal viscera, and in the mediastinum, which are

Fig 4 70 year-old female with cirrhosis of the liver and portal hyp rtension Portal venous pressure 21 cm H O (uncor rected valu) Collateral flow via extremely dilated left gastric and short gastric veins to esophageal varices Transcatheter occlusion of collateral veins with Isobutyl Cyanoacrylate resulted in rise of the portal venous pressure to 35 cm H_2O indicating that the esophageal varices were hemodynamically effective porto-systemic com munications

rarely shown intra vitam (Figs 1 2) As the demonstration of porto systemic collateral flow depends primarily on the site of injection of the contrast medium non filled collaterals do not necessarily mean that a collateral pathway does not exist (Fig 3) Consequently the most important advantage of transhepatic portography and transumbilical portal catheterization as opposed to percutaneous splenic portography is the selective access to the splanchnic veins

Whereas the umbilico portal catheterization (VIALLET et coll 1970) seems to be equivalent to percutaneous transhepatic portography from the diagnostic aspect divergent opinions exist as to the value of percutaneous splenic portography DAGRADI (1973) found that the latter examination demonstrated esophageal varices in only 41 per cent of patients with very large varices at esophagoscopy on the other hand FIGLEY et coll (1955) STEINER et coll (1957) BRUWER & HALLENBECK (1957) EVANS (1959) DOPPMAN & SHAPIRO (1961) observed only single cases with known varices in which no abnormality was found In some cases hepatofugal blood flow in the portal vein can explain the failure of splenic portography in demonstrating esophageal varices

The vascular resistance to the portal venous flow in the normal liver is very low resulting in a corrected portal venous pressure not exceeding 10 cm H_2O (BELLIS 1942) Increasing obstruction of the hepatic veins due to fibrosis and formation of regenerative nodul s in the cirrhotic liver appears to be the most important reason for th pressure rise in the portal and splanchnic venous area (KELTY et coll 1950 HALES et coll 1959 CARTER et coll 1961 PIPER 1961 MITRA 1966) Portal venous hypertension seems to be established when the gradient between the pressure in the portal vein and the liver veins exceeds 12 cm H_2O Hepatofugal blood flow via porto-systemic communications was not observed in the present series when the free (=un corrected) portal venous pressure was below 20 cm H_2O

KEGARIES (1934) and BUTLER (1951) have shown that the sub-mucosal veins of the

Fig 5

Fig 6

Fig 5 54 year old female with cirrhosis of the liver and portal hypertension Portal venous pressur 34 cm H_2O (uncorrected value) Percutaneous transhepatic catheterization of splenic vein Hepato fugal flow via short gastric veins close to the hilum of the spleen to multiple slightly dilated veins i distal segment of the esophagus

Fig 6 36 year old male with cirrhosis of the liver and portal venous hypertension Portal veno pressure 27 cm H_2O (uncorrected value) Selective catheterization of left gastric vein demonstrate in addition to esophageal varices a gastrorenal collateral not filled at previous injection of contra medium into the splenic vein

esophagus and stomach are continuous at the cardia forming anastomoses betwe the portal and systemic veins These veins are of much smaller diameter than th peri esophageal or superficial venous plexus which forms direct communicati channels between the left gastric vein and the azygos and hemiazygos veins (BUTLER In portal venous hypertension both the esophageal and para esophageal veins m dilate and form varicose porto systemic collaterals At selective injection of contra medium into the left gastric vein in patients with portal venous pressure within norm limits in the present series veins belonging to the distal segment of the esophag were never filled

Because esophageal varices are a potential source of hemorrhage their frequenc morphology and size in liver cirrhosis accompanied by various levels of increas portal venous pressure have been extensively discussed in the literature PALM (1953) examined 25 patients by esophagoscopy and measured the varix diamete extent of esophageal involvement and pressure by direct puncture of the vario

Fig 7

Fig 8

ig 7 53 year-old female with cirrhosis of the liver and portal hypertension Portal venous pressure
l cm H O (uncorrected value) Liver dislodged from lateral abdominal wall because of ascites
epatofugal flow via large para umbilical vein No hepatofugal flow via esophageal varices

ig. 8 60-year-old male with cirrhosis of the liver and portal hypertension Portal venous pressure
) cm H O (uncorrected value) Percutaneous transhepatic catheterization of markedly enlarged
ferior mesenteric vein Hepatofugal flow via retroperitoneal collateral in inferior vena cava (→)
orto-systemic anastomosis (↦) very narrow in comparison to feeding collateral vein

ithout any correlation being found between a certain pressure level and the severity f varices among different patients VIALLET et coll (1970) and ROUSSELOT et coll 1959) reported a significant relation between the portal venous pressure and the egree of esophageal varices when performing umbilico portal catheterization or ercutaneous splenic portography However in agreement with BERGSTRAND & EKMAN (1957) and TURNER et coll (1957) no correlation was found in the present eries between the portal venous pressure and the extent of esophageal varices (Figs -6) nor any correlation between portal venous pressure and the number of other orto-systemic collaterals

As in the reports of BERGSTRAND & EKMAN VIALLET et coll and NUNEZ et coll 1978) the left gastric vein was the most important pathway in cranially directed ollateral flow However in 50 of the present 82 patients one or more short gastric eins formed additional tributaries to esophageal varices No esophageal varices combined with normal portal venous pressure were observed contrary to the findings

Fig 9

Fig 9 66 year old male with cirrhosis of the liver and portal hypertension Portal venous pressure 32 cm H_2O (uncorrected value) Percutaneous transhepatic catheterization of spontaneous splenorenal shunt Porto systemic anastomosis (→) narrower than feeding collateral

Fig 10 58 year old male with cirrhosis of the liver and portal hypertension Portal venous pressure 28 cm H_2O (uncorrected value) Hepatofugal flow through large para umbilical vein and inferior epigastric veins to femoral iliac inferior caval veins Porto systemic anastomosis (→) narrower than feeding collaterals

Fig 10

of ROUSSELOT et coll Furthermore in no case did even extremely large porto systemic collaterals result in reduction of the portal venous pressure to normal

Although a wide variety and multiple combinations of porto systemic collaterals were observed in the present series there is no reason to assume that all collaterals were demonstrated in each individual case (Figs 7–10) Sparse porto systemic collaterals were not always correlated with low portal venous pressure and an extensive porto systemic collateral flow was not regularly paralleled by decreasing portal venous pressure The same appearance of porto systemic collaterals was present in cases with a difference in portal venous pressure of 10 to 15 cm H O Consequently, the appearance, extent and width of porto systemic collaterals do not permit any conclusion as to their hemodynamic effectivity in lowering the portal venous pressure

Esophageal varices of various degrees were observed whether or not large para umbilical splenorenal, or mesenterico caval communications were present Contrary to the findings of WEXLER et coll (1975) large porto systemic collaterals in the

present series never reduced the portal venous pressure to normal When the porto systemic anastomosis itself was demonstrated it was regularly much narrower than the feeding collateral (Figs 8–10) which may contribute to its ineffectiveness in reducing the portal venous pressure No correlation was found between the portal venous pressure and the porto systemic collateral flow to the drainage region of the inferior or superior vena cava and the diameter of the portal vein

In conclusion the results confirmed that the portal venous pressure in cirrhosis of the liver is an unreliable parameter of the degree direction and hemodynamic effectiveness of porto-systemic communications In addition it seems to be of little importance in the evaluation of liver cirrhosis (SIMERT et coll)

SUMMARY

In 93 patients with cirrhosis of the liver and portal venous hypertension the main tributaries of the portal vein were examined by percutaneous transhepatic catheterization The appearance and degree of porto systemic collaterals were analysed Esophageal varices were demonstrated in 82 patients No correlation was found between the portal venous pressure and the extent of porto systemic communications

ZUSAMMENFASSUNG

In 93 Fallen von Leberzirrhose und Pfortaderhochdruck wurden die Hauptstamme der Splanchnikusvenen perkutan transhepatisch katheterisiert Die Entwicklung von porto-systemischen Kollateralen wurde analysiert Ösophagusvarizen wurden in 82 Fallen nach gewiesen Keine Beziehung bestand zwischen der Hohe des Pfortaderhochdruckes und dem Ausmass der porto systemischen Kollateralisation

RESUME

Les principales veines tributaires de la veine porte ont éte examinées par cathetérisme transhepatique percutane chez 93 malades atteints de cirrhose du foie et d hypertension veineuse portale Les auteurs étudient les aspects et le degré de circulation collaterale porto systémique Ils ont mis en evidence des varices oesophagiennes chez 82 malades Ils n ont pas trouvé de corrélation entre la pression veineuse portale [illegible] l étendue des communications porto-systémiques

REFERENCES

BELLIS C J The portal venous pressure in man Proc Soc exp Biol 50 (1942) 258

BERGSTRAND I and EKMAN C A Portal circulation in portal hypertension Acta radiol 47 (1957) 1

BRUWER A J and HALLENBECK G A Roentgenologic findings in splenic portography Amer J Roentgenol 77 (1957) 324

BUTLER H The veins of the oesophagus Thorax 6 (1951) 276

CARTER J H WELCH C S and BARRON R E Changes in the hepatic blood vessels in cirrhosis of the liver Surg Gynec Obstet 113 (1961) 133

Fig. 9

Fig. 10

Fig. 9. 66 year old male with cirrhosis of the liver and portal hypertension. Portal venous pressure 32 cm H_2O (uncorrected value). Percutaneous transhepatic catheterization of spontaneous splenorenal shunt. Porto-systemic anastomosis (→) narrower than feeding collateral.

Fig. 10. 58 year old male with cirrhosis of the liver and portal hypertension. Portal venous pressure 28 cm H_2O (uncorrected value). Hepatofugal flow through large para-umbilical vein and inferior epigastric veins to femoral-iliac-inferior caval veins. Porto-systemic anastomosis (→) narrower than feeding collaterals.

of ROUSSELOT et coll. Furthermore in no case did even extremely large porto-systemic collaterals result in reduction of the portal venous pressure to normal.

Although a wide variety and multiple combinations of porto-systemic collaterals were observed in the present series, there is no reason to assume that all collaterals were demonstrated in each individual case (Figs. 7–10). Sparse porto-systemic collaterals were not always correlated with low portal venous pressure and an extensive porto-systemic collateral flow was not regularly paralleled by decreasing portal venous pressure. The same appearance of porto-systemic collaterals was present in cases with a difference in portal venous pressure of 10 to 15 cm H_2O. Consequently, the appearance, extent and width of porto-systemic collaterals do not permit any conclusion as to their hemodynamic effectivity in lowering the portal venous pressure.

Esophageal varices of various degrees were observed whether or not large para-umbilical, splenorenal or mesenterico-caval communications were present. Contrary to the findings of WEXLER et coll. (1975) large porto-systemic collaterals in the

PEREIRAS R VIAMONTE M JR RUSSELL E LE PAGE J WHITE P and HUTSON D New techniques for interruption of gastroesophageal venous blood flow Radiology 124 (1977) 313

PIPER D W A radiographic study of the portal and hepatic venous systems in cirrhosis of the liver Amer J dig Dis 6 (1961) 499

RETZIUS A A Bemerkungen uber Anastomosen zwischen der Pfortader und der untern Hohlader ausserhalb der Leber Z Physiol 5 (1835) 105

ROUSSELOT L M MORENO A H and PANKE W F Studies on portal hypertension IV The clinical and physiopathologic significance of self established (nonsurgical) portal systemic venous shunts Ann Surg 150 (1959) 384

SCOTT J DICK R LONG R G and SHERLOCK S Percutaneous transhepatic obliteration of gastro oesophageal varices Lancet II (1976) 53

SIVERT G LUNDERQUIST A TYLÉN U and VANG J Correlation between percutaneous transhepatic portography and clinical findings in 56 patients with portal hypertension Acta chir scand 144 (1978) 27

STEINER R E SHERLOCK S and TURNER M D Percutaneous splenic portal venography J Fac Radiol 8 (1957) 158

THAMM M Die portocavalen Venenverbindungen des Menschen Zbl Chir 39 (1940) 1828

TURNER M D SHERLOCK S and STEINER R E Splenic venography and intrasplenic pressure measurement in the clinical investigation of the portal venous system Amer J Med 73 (1957) 846

VIALLET A LEGARE A and LAVOIE P Hepatic and umbilicoportal catheterization in portal hypertension Ann N Y Acad Sci 170 (1970) 177

VIAMONTE M JR PEREIRAS R RUSSELL E LE PAGE J and HUTSON D Transhepatic obliteration of gastroesophageal varices Results in acute and nonacute bleeders Amer J Roentgenol 129 (1977) 237

WEXLER M J and MACLEAN L D Massive spontaneous portal systemic shunting without varices Arch Surg 110 (1975) 995

WIDRICH W C ROBBINS A H NABSETH D C JOHNSON W C and GOLDSTEIN S A Pitfalls of transhepatic portal venography and therapeutic coronary vein occlusion Amer J Roentgenol 131 (1978) 637

COOPERMAN A M and ALFIDI R J Transhepatic variceal sclerotherapy Arch Surg 111 (1976) 609

DAGRADI A E Esophageal varices splenic pulp pressure and directional flow patterns in alcoholic liver cirrhosis Amer J Gastroenterol 59 (1973) 15

DEIMER E FUNOVICS J und MÜLLER M Zur transhepatischen Verodung blutender Ösophagusvarizen bei der Leberzirrhose Fortschr Rontgenstr 128 (1978) 119

DOFFMAN J L and SHAPIRO R Bleeding esophageal varices in the presence of a normal splenoportogram Amer J Roentgenol 86 (1961) 1103

DOYON D MOUZON A VADROT D FRANCO D et BISMUTH H Embolisation transhépatique des varices oesophagiennes J Radiol Électrol 56 (1975) 917

EDWARDS E A Functional anatomy of the porta systemic communications Arch intern Med 88 (1951) 137

EVANS K T Oesophageal and gastric varices Brit J Radiol 32 (1959) 233

FIGLEY M M FRY W J OREBAUGH J E and POLLARD H M Percutaneous splenoportography Gastroenterology 28 (1955) 153

GUNTHER R GEORGI M KURTENBACH P BRUNNER H und SCHMIDT H D Perkutane transhepatische Pfortadersondierung mit Verodung blutender Ösophagusvarizen Dtsch med Wschr 101 (1976) 1491

— KURTENBACH P GEORGI M SCHMIDT H D und FARACK U Perkutane transhepatische Thrombosierung der Vena coronaria ventriculi bei Ösophagusvarizenblutung Fortschr Rontgenstr 126 (1977) 6

HALES M R ALLAN J S and HALL E M Injection-corrosion studies of normal and cirrhotic livers Amer J Path 35 (1959) 909

HOEVELS J Ergebnisse der perkutanen transhepatischen Portographie Fortschr Rontgenstr 128 (1978) 432

— LUNDERQUIST A and TYLÉN U Percutaneous transhepatic portography Acta radiol Diagnosis 19 (1978) 643

KEGARIES D L The venous plexus of the oesophagus Surg Gynec Obstet 58 (1934) 46

KELLER F S DOTTER C T and RÖSCH J Percutaneous transhepatic obliteration of gastroesophageal varices Some technical aspects Radiology 129 (1978) 327

KELTY R H BAGGENSTOSS A H and BUTT H R The relation of the regenerated liver nodule to the vascular bed in cirrhosis Gastroenterology 15 (1950) 285

LUNDERQUIST A and VANG J Transhepatic catheterization and obliteration of the coronary vein in patients with portal hypertension and esophageal varices New Engl J Med 291 (1974) 646

— — Sclerosing injection of esophageal varices through transhepatic selective catheterization of the gastric coronary vein A preliminary report Acta radiol Diagnosis 15 (1974) 546

— BÖRJESSON B OWMAN T and BENGMARK S Isobutyl 2 Cyanoacrylate (Bucrylate) in obliteration of gastric coronary vein and esophageal varices Amer J Roentgenol 130 (1978) 1

— SIMERT G TYLÉN U and VANG J Follow up of patients with portal hypertension and esophageal varices treated with percutaneous obliteration of gastric coronary vein Radiology 122 (1977) 59

MITRA S K Hepatic vascular changes in human and experimental cirrhosis J Path Bact 92 (1966) 405

NUNEZ D JR RUSSELL E YRIZARRY J PEREIRAS R and VIAMONTE M JR Portosystemic communications studied by transhepatic portography Radiology 127 (1978) 75

PALMER E D On correlations between portal venous pressure and the size and extent of esophageal varices in portal cirrhosis Ann Surg 138 (1953) 741

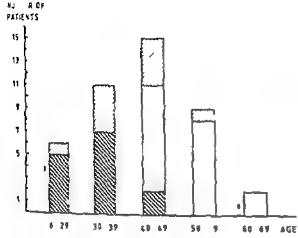


Fig 1 Forty three patients with unilateral renal artery stenosis or occlusion Distribution by age sex and type of vascular lesion ▭ atheromatosis ▭ fibromuscular dysplasia, ▭ other or not specified type of stenosis M = male F = female

However opinions differ about the reliability of this method for predicting which patients will benefit from operation

BOOKSTEIN (1966) evaluated the angiographic criteria of hemodynamically significant stenosis which was defined as a pressure gradient of more than 30 mmHg across the stenosis on operation or decreased renal turgor or decreased renal artery pulsations He found that stenoses of the main renal artery with a diameter of 1 5 mm or less always were hemodynamically significant and stenoses with a diameter of 1 6 to 3 mm in half of the cases Collateral circulation always indicated hemodynamic significance Unilaterally decreased blood flow was also considered an important sign Poststenotic dilatation on the other hand was present just as often in significant as in nonsignificant stenoses About 75 per cent of patients with hemodynamically significant stenosis had a favorable response to surgery

DELIN et coll (1966) compared renal artery stenosis demonstrated at angiography with recordings of pressure and volumetric flow rate during operation From these data the resistance of the stenoses was calculated A good correlation between very severe stenoses and a high resistance to flow was found In severe moderate and mild stenoses the results were not conclusive Neither diameter nor per cent reduction of the lumen area in the stenoses were given

BROLIN (1967) considered collateral circulation and decreased blood flow to be a reliable indication of hemodynamically significant stenosis She was of the opinion however that the indication for surgery could not be determined on the basis of the angiography alone

The significance of collateral circulation as an indicator of a significant stenosis was again emphasized by BOOKSTEIN & WALTER (1975) By observing the direction of blood flow in distal nonparenchymal branches of the renal artery after injection of vasodilatory and vasoconstrictive agents in the renal artery enhanced informa

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UNILATERAL RENAL ARTERY STENOSIS AND HYPERTENSION

I Angiography

INGVAR ANDERSSON

Most cases of renovascular hypertension are caused by stenosis or occlusion of the main stem of the renal artery or one of its primary branches. However such a stenosis is not necessarily responsible for hypertension (EYLER et coll. 1962, DUSTAN et coll. 1964, HOLLEY et coll. 1964). In the evaluation of a patient with possible renovascular hypertension a pathogenic relationship between a renal artery stenosis and hypertension must be proved or excluded.

Several methods have been used to determine the functional significance of a stenosis. Split renal function tests (HOWARD et coll. 1954) have been widely used in the past but have now been replaced by renin assay in most centers (ERNST et coll. 1972, JUNCOS et coll. 1974, COUCH et coll. 1976). As a result of a significant renal artery stenosis, i.e. a stenosis which is responsible for hypertension, the plasma renin activity is higher in venous blood from the kidney with a stenotic artery as compared with the normal kidney (MICHELAKIS et coll. 1967, STOCKIGT et coll. 1972, MARKS & MAXWELL 1975). However, negative tests in patients improved or cured by surgery and positive tests in unimproved patients have been reported. In a compilation of their own material and cases from the literature MARKS et coll. (1976) found 57 per cent false negatives (88/155) and 7 per cent false positives (22/313).

Nephroangiography is indispensable in the delineation of the vascular anatomy

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Fig. 3 43-year-old woman Semiselective angiography Left posterior projection Tip of catheter placed in right renal artery Short stenosis of not specified type in the right renal artery Diameter of stenosis 1 mm Marked poststenotic dilatation Proximal to stenosis a uniform moderate narrowing of the artery Abundant collateral circulation from adrenal (→) and lumbar arteries (↔)

been operated upon at another hospital with a non functioning spleno renal arterial reconstruction Thus 43 patients remain for analysis None of the patients had any stenosis in the contralateral renal artery

The distribution by age sex and type of vascular lesion is given in Fig 1 The determination of the type of vascular lesion was based on morphologic examination or the findings at operation in 27 cases Eight stenoses of the proximal tapering type were classified as atheromatosis on the basis of the radiologic appearance (Fig 2) One case represented an embolic occlusion and 1 case an iatrogenous lesion In 6 cases the type of stenosis could not be determined

Angiographic procedures In 26 cases the preoperative nephroangiography had been performed at other hospitals in 18 of these lumbar aortography only in the remaining cases in addition selective nephroangiography

At this institution patients with hypertension were examined with a semiselective technique followed by selective examination of one or both kidneys In the semi selective one a catheter (OD/ID 2 2/1 45 mm) with a long tapered end (OD/ID 1 4/1 0 mm) and 8 sideholes proximal to the tapered part was used The tapered end of the catheter had such a shape that it could be introduced into the orifice of one of the renal arteries allowing simultaneous injection into that artery and into the aorta

Fig. 2. 44 year old man. Semiselective angiography. The right kidney supplied by 2 arteries. Proximal tapering stenosis of atheromatosis type in the ventral artery. Minimum diameter of stenosis 1 mm. Moderate poststenotic dilatation.

tion of collateral flow may be obtained (BOOKSTEIN & ERNST 1973, BOOKSTEIN et coll. 1976).

BOOKSTEIN et coll. (1972 a) concluded that angiography has only limited value in predicting the response to surgery. MAXWELL et coll. (1967) was of the opinion that *the arteriogram does not serve to identify a functional lesion and is therefore not truly diagnostic of renovascular hypertension*. The same opinion was held by JUNCOS et coll. Nephroangiography was considered extremely valuable by FOSTER et coll. (1973) in the evaluation of patients with hypertension although with several limitations, e.g. lack of precision in grading the severity of a stenosis.

In view of the diverse opinions in the literature it was considered important to analyse the role of nephroangiography in predicting the blood pressure response following surgery in patients with possible renovascular hypertension. An attempt was also made to define angiographic criteria characterizing a significant renal artery stenosis, i.e. a stenosis which might be responsible for hypertension. In this report the lesions demonstrated at preoperative nephroangiography of patients with unilateral renal artery stenosis or occlusion are presented and their significance discussed. In a following report the angiographic findings will be correlated with the blood pressure response following operation.

Material and Methods

The material consisted of preoperative nephroangiography of 49 patients with unilateral renal artery stenosis or occlusion, who were subjected to reconstructive surgery or nephrectomy at this hospital during 1971 through 1975. Six patients were excluded: 2 patients who died in the immediate postoperative period, 1 patient with stenosis and severe hydronephrosis, 1 patient with a posttraumatic dissecting aneurysm, 1 patient with stenosis and a contracted kidney and 1 patient who had previously

Table 1

Diameter of stenosis versus part of kidney involved by stenosis or occlusion

Part of kidney involved ( )	Diameter of stenosis (mm)				Total
	Occl	≤1	≤2	>2≤3	
100	3	7	16	3	29
51–90		3	5		8
25–50	4	2			6
Total	7	12	21	3	43

Table 2

Lumen area reduction versus part of kidney involved by stenosis or occlusion

Part of kidney involved ( )	Reduction of lumen area ( )				Total
	<80	80–89	90–99	100	
100		3	23	3	29
51–90			8		8
25–50	1		1	4	6
Total	1	3	32	7	43

part of the artery was assumed to be circular although it was realized that the constriction in antero posterior direction might differ from that in cranio caudal direction

Eighteen stenoses were measured independently by another radiologist with complete agreement in 16 cases and a deviation of 0 5 mm in 2 cases In none of the cases did the value obtained on repeated measuring exceed that of the original measuring

Results

In 7 patients occlusion of the renal artery or its branches was found and in 36 stenosis The right renal artery was engaged in 22 cases and the left in 21 Fibromuscular dysplasia engaged the right kidney in 8 cases and in 6 the left one Atheromatosis was found in 8 cases on the right side and in 10 on the left Multiple renal arteries existed in 17 patients (40) on the stenotic side in 7 patients and on the nonstenotic side in 5 and on both sides in 5 patients

Si e of stenosis The stenosis was exactly delineated in 14 cases but inexactly in 22 which was due to either of two reasons (1) Short stenosis with central beam not

Fig 4 25 year old man Semi selective nephroangiography Subtraction film Short stenosis (fibromuscular dysplasia) in one of two right renal arteries (→) Beam direction not parallel to the plane of the stenosis Diameter of stenosis 1 5 mm or less Poststenotic dilatation

(Figs 2 3) Thirty ml of contrast medium (280–370 mg I/ml) were injected at a rate of 20 ml/s 5 to 7 ml passing through the top hole Serial films were obtained at a rate of 2 per s for 3 s 1 per s for 3 s and 1 every other second for 6 seconds FFD was 100 cm An a p series was first exposed Depending on the findings in this initial series the continued examination was individualized

The selective angiography was performed with the same type of catheter but without sideholes A direct magnification technique was introduced in 1974 with a microfocus of 0 1 or 0 2 no grid and with FFD 100 cm focus—skin distance 17 to 30 cm A magnification of 2 2 to 3 6 of the kidney was achieved

The films were reviewed without knowledge of the surgical findings and the following factors recorded (1) Number of renal arteries (2) diameter of stenosis and diameter of the unconstricted part of the artery or when this was not possible diameter of the contralateral renal artery, (3) the part of the kidney supplied by the stenotic artery (4) collateral circulation (5) poststenotic dilatation (6) lesions of the intrarenal arteries and cortex and (7) length of the kidneys local reduction of size

The measurements were made with a transparent ruler graded in millimeters directly on the film The figures were not reduced for the magnification of FFD 100 cm with the patient on top of the film changer The magnification of the kidney may be estimated to 20 per cent

The lumen area reduction was calculated according to the formula

$$\text{per cent lumen area reduction} = \frac{A - B}{A} \times 100,$$

where A = the lumen area of the unstenosed vessel and B = the lumen area of the stenosis In these calculations the lumen of the stenosed as well as the unstenosed

Fig 5 35 year old woman with a severe stenosis (fibromuscular dysplasia) in one of two right renal arteries Branches of the stenotic artery (→) are supplied through abundant collaterals from the unstenosed artery (reno-renal collaterals)

from a single artery was occluded in the remaining cases stenosis or occlusion occurred in kidneys supplied by two arteries In 4 cases adrenal arteries (Fig 3) or ureteric arteries (Fig 6) dominated as collaterals Inflow of blood not containing contrast medium into a hilar branch indirectly indicated collateral circulation in one case

In the youn est age group collateral circulation was demonstrated in 7/8 cases (88 Table 3) and in the oldest age group in only 2/12 (17) The difference is significant (p < 0 01) Collateral circulation was demonstrated in 12/14 cases (86 %) with fibromuscular dysplasia and in 6/19 cases (32 %) with atheromatosis (p < 0 002)

Poststenotic dilatation existed in 34/36 arteries (94) slight in 10 cases moderate in 18 and severe in 6 All arteries with a diameter of stenosis between 2 and 3 mm had a poststenotic dilatation Short stenoses with a right angled inlet tended to produce a severe poststenotic dilatation while stenoses with a long tapering prestenotic segment tended to produce a slight poststenotic dilatation

Intrarenal arterial lesions and cortical lesions The following abnormalities were recorded tortuosity abnormal tapering irregular lumen and occlusions of the intra

Table 3

Collateral circulation in relation to age of the patients and type of stenosis Per cent within parentheses

Age	Fibromuscular dysplasia +/−	Atheromatosis +/−	Other +/−	Total
< 30	4/1		3/0	7/1 (88)
30–49	8/1	5/4	3/2	16/7 (70)
50 69		1/9	1/1	2/10 (17)
Total	12/2 (86)	6/13 (32)	7/3 (70)	25/18 (58)

+ collateral circulation
− no collateral circulation

parallel to the plane of stenosis (Fig 4) In these cases the pre or poststenotic segment was more or less superimposed on the stenosis Thus the true diameter may have been less than the diameter recorded (2) Insufficient resolution or too low a contrast in the area of maximum stenosis for exact delineation In these cases only an upper and a lower limit could be given In cases of fibromuscular dysplasia with multiple stenoses the maximum stenosis was measured

The normal diameter of the stenotic artery could be measured in 16 cases but not in the remaining 20 In most cases this was due to the stenosis being located near the origin with poststenotic dilatation of the remaining part of the main stem In these 20 cases the calculation of lumen area reduction was based on measurements of the contralateral artery

It is evident from Table 1 that in 40/43 cases (93 %) either occlusion or a diameter of the stenosis of 2 mm or less was found Three patients had a stenosis diameter of between 2 and 3 mm one of these had only one kidney In 29 cases the stenosis or occlusion engaged the main stem of a single artery Fourteen cases had a stenosis or occlusion in one of multiple arteries or in a branch Thirty nine of 43 cases (91 %) had a reduction of lumen area of 90 per cent or more (Table 2) In all cases but one with a stenosis diameter of 2 mm or less the reduction of lumen area was more than 90 per cent The exception was a branch stenosis In the cases with a diameter of stenosis between 2 and 3 mm the reduction of lumen area varied between 80 and 90 per cent

Collateral circulation was demonstrated in 25/43 cases (58 % Table 3) lumbar arteries being the most common source These arteries were the single source in 5 cases and combined with other arteries in 8 cases (Fig 3) Collaterals between branches of a single artery or between multiple arteries ('reno renal' collaterals) occurred in 7 cases and were the only type in 5 (Fig 5) In one of these 7 cases a branch

Table 4

Occurrence of intrarenal arterial abnormalities or cortical lesions

Type of stenosis (No of cases)	Ipsi lateral	Contra lateral	Bi lateral	No abnor mality
Fibromuscular dysplasia (13)	3	2		8
Atheromatosis (17)	4		6	7
Other (8)	1			7
Total	8	2	6	22

he normal left kidney exceeds that of the normal right kidney by a mean of 0 3 m The reduction of the length of the kidney affected by stenosis was calculated as ength of the normal kidney minus length of the kidney affected by stenosis with correction for the normal difference The kidney length was reduced less than 1 cm n 20 cases 1 to 1 5 cm in 6 and more than 1 5 in 15 Of the 20 patients with a reduc ion of less than 1 cm the stenosis or occlusion engaged only part of the kidney in 12 cases (main stem stenosis in one of multiple arteries in 9 cases and branch stenosis or occlusion in 3 cases) In all but one of these cases a local reduction of volume was found in the area supplied by the stenotic or occluded artery (Fig 7) The remaining 8 cases with a reduction of less than 1 cm had a stenosis in the main stem of single arteries

Discussion

Several factors influence the hemodynamic effects of a stenosis the most important being the diameter of the stenosis and the volumetric flow rate which in turn depends on the resistance to flow in the peripheral vessels Experimental as well as clinical experience indicates that the constriction of an artery must be considerable before any perceptible reduction of pressure and volumetric flow rate distal to the constric tion occurs (HAIMOVICI & ZINICOLA 1962 MAY et coll 1963) Once a certain degree of stenosis has been reached (critical stenosis) further constriction of the lumen has a considerable hemodynamic effect The critical stenosis is related to the volumetric flow rate Thus a specific degree of stenosis may be critical at a particular peripheral resistance but not if the peripheral resistance is increased (LUPU et coll 1968) By measuring the degree of stenosis at angiography and pressures and flow rates during operation MAY et coll concluded that the critical stenosis for the human renal artery is about 82 per cent reduction of its transverse area

In the present material 40 of 43 patients had either occlusion of the renal artery or a stenosis with a diameter of 2 mm or less With one exception the reduction of lumen area was calculated to be 90 per cent or more in these cases Three patients had a diameter of the stenosis between 2 and 3 mm with the reduction of lumen area varying between 80 and 90 per cent

a b

Fig. 6. 23 year old woman with fibromuscular dysplasia in the right renal artery. a) Selective angiography. Slight uniform narrowing of a long segment of the main stem with severe stenosis in the most distal part. One of the main branches is dilated with slight constrictions (string of beads). b) Semiselective angiography, parenchymatous phase. A wide tortuous ureteric artery serves as collateral vessel to the renal artery.

renal arteries, irregular cortical surface, localized reduction of the width of the cortex and an irregular nephrographic effect in the cortex. In 13 of the cases listed in Table 4 only aortography had been performed. Thus minor abnormalities may not have been demonstrated. Five cases were excluded as the peripheral arterial branches were poorly demonstrated.

Intrarenal arterial lesions or cortical lesions occurred in 16 patients (Table 4). The lesions were confined to the kidney supplied by the stenotic artery in 8 cases (Fig. 7) and in 2 cases to the contralateral kidney. Six patients, all with atherosclerotic stenosis, had bilateral lesions. Two patients had only cortical abnormalities and 7 only arterial. Thus, in 7 patients arterial as well as cortical lesions existed. Most frequent was tortuosity of the intrarenal arterial branches.

Reduction of the size of the kidney affected by stenosis. According to EKLÖF & RINGERTZ (1976) the length of a kidney is representative of its size. The length of the kidneys was measured from pole to pole in the parenchymatous phase of the aortic or semiselective series in a.p. projection. According to MOELL (1961) the length of

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a

b

c

Fig 7 38 year old woman Semiselective angiography Stenosis (fibromuscular dysplasia) in the artery supplying the upper half of the left kidney a) Intrarenal branches of the artery affected by stenosis are tortuous b) Intrarenal branches of the nonstenosed artery normal c) Upper half of kidney is reduced and cortex irregular

The length of a stenosis is of some but considerably less importance than the factors mentioned (FIDDIAN et coll 1964 BJORNO & PETTERSSON 1977) The length of the stenoses was not measured in the present material as in a large number of cases the renal artery tapered towards the area of maximum stenosis making a

definition of the length of the stenosis difficult Neither has the length of involvement in cases with fibromuscular dysplasia in the form of a string of beads been taken into account Based on clinical and experimental evidence it has been claimed that fibromuscular dysplasia of this type might provoke hypertension by changing the pulse wave characteristics even in the absence of stenosis (REICH et coll 1975)

Some uncertainties associated with the measurement of renal artery stenoses on the films must be realized Factors such as superimposition of splanchnic arteries or insufficient resolution in the films influence the measurement If the beam direction is not parallel to the plane of a short stenosis it may be falsely evaluated or even pass unrecognized The course of the renal arteries is often more or less antero posterior rather than transverse (FOSTER et coll 1969 DEAN et coll 1974) Thus a short stenosis may be partly obscured in an a p projection The same applies to a stenosis located at the orifice of a renal artery if the artery originates from the anterior or posterior aspect of the aorta Adequate projections chosen with respect to the anatomy in the individual case will reduce these difficulties In the present material care was taken not to overestimate the diameter of a stenosis In some cases the diameter was probably less than that recorded The calculation of the reduction of lumen area which is the adequate parameter from a hemodynamic point of view was based on measurement of the cranio caudal diameter of the artery assuming that the lumen in the constricted and unconstricted part of the artery was circular Clearly the constriction of the artery in an antero posterior direction might have differed from that in a cranio caudal direction In two cases a marked reduction of the attenuation was noted in part of the stenotic segment indicating a more severe constriction in the antero-posterior direction than was evident from the cranio-caudal diameter

The tapered end of the catheter used for the semiselective examinations rarely caused spasm When it occurred it was of slight degree and could easily be differentiated from an organic lesion

Collateral circulation reflects a pressure gradient between two vascular regions Consequently collateral circulation has been considered a reliable indication of hemodynamically significant stenosis (BOOKSTEIN BROLIN ERNST et coll BOOKSTEIN & WALTER)

It is not clear why a considerable number of patients with renovascular hypertension do not have a collateral circulation The present material suggests that age might be one factor The technique of examination and image quality may also be considered For instance renorenal collaterals may be overlooked unless selective injections are performed This type of collateral circulation first described by BROLIN seems to be the main route in branch stenosis and in cases with stenosis in one of multiple arteries (ROSENBUSCH et coll 1974)

Furthermore the peripheral vascular resistance during the examination is another factor The influence of this factor on pressure gradient over a stenosis was experimentally investigated by LUPU et coll and THOMAS et coll (1968) who found that a reduction of peripheral vascular resistance increased the pressure gradient and an

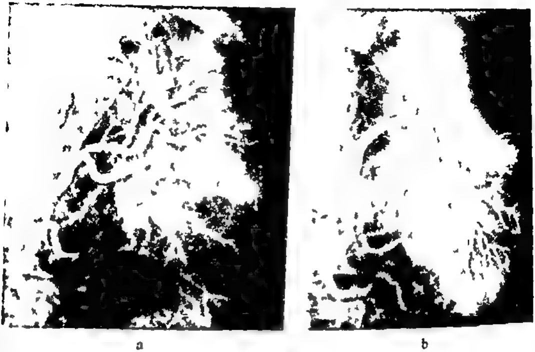

Fig 7 38 year old woman Semiselective angiography Stenosis (fibromuscular dysplasia) in the artery supplying the upper half of the left kidney a) Intrarenal branches of the artery affected by stenosis are tortuous b) Intrarenal branches of the nonstenosed artery normal c) Upper half of kidney is reduced and cortex irregular

The length of a stenosis is of some but considerably less importance than the factors mentioned (FIDDIAN et coll 1964 BJORNO & PETTERSSON 1977) The length of the stenoses was not measured in the present material as in a large number of cases the renal artery tapered towards the area of maximum stenosis making a

Much attention has been drawn to the relationship between intrarenal vascular disease (arteriolar sclerosis nephrosclerosis) and hypertension It has been claimed that the presence of arteriolar sclerosis precludes a favorable response to surgery (VERTES et coll 1965) In contrast VIDT et coll (1972) found no correlation between the presence of arteriolar sclerosis in renal biopsies and the outcome of surgery Furthermore opinions differ on the existence of specific angiographic signs of nephrosclerosis HOLLENBERG et coll (1969) found a good correlation between lesions of interlobar and arcuate arteries demonstrated at angiography in patients with essential hypertension and clinical and laboratory indices of hypertension Similar lesions although less frequent and of minor degree were found in normotensive patients MENA et coll (1973) could differentiate between chronic glomerulonephritis chronic pyelonephritis and advanced arteriolonephrosclerosis in 88 per cent of cases On the other hand GILL & PUDVAN (1970) found no discriminatory features of nephrosclerosis glomerulonephritis and pyelonephritis In a critical review of information derived from various methods reflecting the morphology and function of the renal vascularity DAVIDSON & TALNER (1973) found that the intrarenal arteries respond similarly to a variety of diseases They concluded that generally the angiography does not permit specific (pathologic) diagnosis of the lesion

However the localization of intrarenal arterial lesions offers some information on their nature Nephrosclerosis if secondary to hypertension caused by a unilateral renal artery stenosis should affect primarily the contralateral kidney Lesions confined to the stenotic kidney which was more frequent in the present material should have a [illegible] se i e the stenosis Some of the abnormalities such as tortuosity of the intr[illegible]teries may be caused by the decreased volume of the kidney Another possibl[illegible]ation for ipsilateral lesions would be embolization from the stenotic or pos[illegible] region of the artery with obliteration in the peripheral vessels In animal[illegible]ents embolization has been shown to cause rather unspecific late lesions [illegible] small cortical scars and arterial pruning and a decrease in kidney volum[illegible] et coll 1976)

On [illegible]ary bilateral lesions may represent a nephrosclerosis secondary to an essent[illegible]rtension or a parenchymatous disease such as glomerulonephritis the stenosis in the renal artery being a secondary lesion

SUMMARY

The preoperative angiographic findings in 43 patients with unilateral renal artery stenosis or occlusion were reviewed in order to record abnormalities such as diameter of stenosis collateral circulation poststenotic dilatation and reduction of kidney size The significance of the various lesions is discussed

ZUSAMMENFASSUNG

Die präoperativen angiographischen Befunde bei 43 Patienten mit unilateraler renaler arterieller Stenose oder Okklusion wurden nachuntersucht in der Absicht Veränderungen

increase reduced the gradient Pharmacologic manipulation to increase or decrease the peripheral resistance has been advocated as a means of revealing hemodynamically significant stenosis by reversal of the flow in collateral pathways (BOOKSTEIN & ERNST BOOKSTEIN et coll 1976)

The mechanism producing poststenotic dilatation has been the subject of several investigations HOLMAN (1954) suggested that an elevated lateral pressure in the poststenotic region might play an important role in the development of the post stenotic dilatation However later reports indicate that the pressure is reduced rather than elevated in the poststenotic region compared with the prestenotic one (DE VRIES & VAN DEN BERG 1958 RODBARD et coll 1967) DE VRIES & VAN DEN BERG suggested that the high frequent vibrations resulting from the turbulence in the poststenotic region might affect the elastic fibers of the arterial wall by structural fatigue and subsequent rupture Furthermore the reduced lateral pressure by simulating a venous type of perfusion might result in a functional adaptation of the elastic fibers leading to a weakening of the arterial wall The combined effects of these factors might account for the poststenotic dilatation Obviously the prerequisites for poststenotic dilatation were present in all but 2 of the non occluded arteries in the present series The absence of poststenotic dilatation may be explained by altered elastic properties of the arterial wall or the surrounding tissues

The majority of the present patients with poststenotic dilatation had a reduction of luminal area of 90 per cent or more However also less marked stenoses may cause poststenotic dilatation SUTTON et coll (1961) found poststenotic dilatation in about half of the patients with stenosis reducing luminal diameter by 50 per cent (i e luminal area by 75 per cent) BOOKSTEIN et coll (1972 a) observed poststenotic dilatation in 13 per cent of stenoses reducing luminal diameter less than 50 per cent

In the presence of a renal artery stenosis the size of the kidney supplied by the stenosed artery is often decreased constituting an important urographic indication of unilateral renal artery stenosis (BOOKSTEIN et coll 1972 b) It is reasonable to believe that this is due in part to a fall in blood pressure but other factors e g atrophy of the renal parenchyma may also play a part A considerable reduction of the kidney volume during pentothal anesthesia was observed by HODSON (1961) This was attributed to a fall in blood pressure COLLIER & SWANN (1971) demonstrated experimentally in dogs a linear relationship between kidney weight and blood pressure in the range of 20 to 80 mmHg at 20 mmHg the kidneys decreased 40 per cent in weight GÖTHLIN & OLIN (1973) found that a moderate fall in blood pressure decreased renal blood flow and renal vascular volume as demonstrated by a dye dilution technique

It is clear from the present material that the reduction of the kidney size caused by a stenosis even if severe is not always enough to reduce the length by 1 cm or more This applies especially to stenosis or occlusion of a branch or of one of multiple arteries However in the majority of such cases a local reduction of the kidney parenchyma was found

Exlöf [redacted] and Ringertz H Kidney size in children A method of assessment Acta radiol Diagnosis 17 (1976) 617

Ernst C B Bookstein J J Montie J Baumgartel E Hoobler S W and Fry W J Renal vein renin ratios and collateral vessels in renovascular hypertension Arch Surg 104 (1972) 496

Eyler W R Clark M [redacted] Garman J E Rian [redacted] L and Meininger D E Angiography of the renal area including a comparative study of renal arterial stenoses in patients with and without hypertension Radiology 78 (1962) 879

Fiddian R V Byar D and Edwards E Factors affecting flow through a stenosed vessel Arch Surg 88 (1964) 105

Foster J H Klatte E C and Burko H Arteriographic pitfalls in the diagnosis of renovascular hypertension Arch Surg 99 (1969) 792

— Dean R H Pinkerton J A and Rhamy R K Ten years experience with the surgical management of renovascular hypertension Ann Surg 177 (1973) 755

Gill W M Jr and Pudvan W R The arteriographic diagnosis of renal parenchymal diseases Radiology 96 (1970) 81

Gothlin J and Olin T Dye dilution technique with nephroangiography for the determination of renal blood flow and related parameters Acta radiol Diagnosis 14 (1973) 113

Haimovici H and Zinicola N Experimental renal artery stenosis Diagnostic significance of arterial hemodynamics J cardiovasc Surg 3 (1962) 259

Hodson C J Physiological changes in size of the human kidney Clin Radiol 12 (1961) 91

Hollenberg N [redacted] Epstein M Basch R I and Merrill J P No man s land of the renal vasculature An arteriographic and hemodynamic assessment of the interlobar and arcuate arteries in essential and accelerated hypertension Amer J Med 47 (1969) 845

Holley K E Hunt J C Brown A L Jr Kincaid O W and Sheps Sh G Renal artery stenosis A clinical pathologic study in normotensive and hypertensive patients Amer J Med 37 (1964) 14

Holman E The obscure physiology of poststenotic dilatation Its relation to the development of aneurysms J thorac Surg 28 (1954) 109

Howard J E Berthrong M Gould D M and Yendt E R Hypertension resulting from unilateral renal vascular disease and its relief by nephrectomy Bull Johns Hopk Hosp 94 (1954) 51

Juncos L I Strong C G and Hunt J C Prediction of results of surgery for renal and renovascular hypertension Arch intern Med 134 (1974) 655

Kelly K M Craven J D Jorgens J and Barenfus M Experimental renal artery thromboembolism Invest Radiol 11 (1976) [redacted]

Lupu A N Kaufman J J and Maxwell [redacted] Renal artery constriction Physiological determinants of pressure gradients Ann Surg 167 (1968) 246

Marks L S and Maxwell M H Renal vein renin Value and limitations in the prediction of operative results Urol Clin N Amer 2 (1975) 311

— — Varady P D Lupu A N and Kaufman J J Renovascular hypertension Does the renal vein renin ratio predict operative results? J Urol 115 (1976) 365

Maxwell M H Lupu A N and Franklin S S Clinical and physiological factors determining diagnosis and choice of treatment of renovascular hypertension Circulat Res 20 and 21 (1967) Suppl No II p 201

May A G van den Berg L DeWeese J A and Rob Ch G Critical arterial stenosis Surgery 54 (1963) 250

Mena E Bookstein J J and Gikas P W Angiographic diagnosis of renal parenchymal disease Radiology 108 (1973) 523

Michelakis A M Foster J H Liddle G W Rhamy R K Kuchel O and Gordon

wie die des Diameters der Stenose Kollateral Zirkulation poststenotische Dilatation und Reduktion der Nierengrosse festzustellen Die Bedeutung der verschiedenen Schädigungen wird diskutiert

RÉSUME

L auteur a revu les signes angiographiques préopératoires chez 43 malades atteints de sténose ou d occlusion unilatérale de l artère rénale pour noter les anomalies telles que le diamètre de la sténose la circulation collaterale la dilatation post sténotique et la réduction des dimensions du rein Il examine l importance des différentes lésions

REFERENCES

BJORNO L and PETTERSSON H Hydro and hemodynamic effects of catheterization of vessels V Experimental and clinical catheterization of stenoses Acta radiol Diagnosis 18 (1977) 193

BOOKSTEIN J J Appraisal of arteriography in estimating the hemodynamic significance of renal artery stenoses Invest Radiol 1 (1966) 281

— and ERNST C B Vasodilatory and vasoconstrictive pharmacoangiographic manipulation of renal collateral flow Radiology 108 (1973) 55

— and WALTER J F The role of abdominal radiography in hypertension secondary to renal or adrenal disease Med Clin N Amer 59 (1975) 169

— — STANLEY C J and FRY W J Pharmacoangiographic manipulation of renal collateral blood flow Circulation 53 (1976) 328

— ABRAMS H L BUENGER R E REISS M D LECKY J W FRANKLIN S S BLEIFER K H VARADY P D and MAXWELL M H (a) Radiologic aspects of renovascular hypertension Part 3 Appraisal of arteriography J Amer med Ass 221 (1972) 368

— — — LECKY J FRANKLIN S S REISS M D BLEIFER K H KLATTE E C VARADY P D and MAXWELL M H (b) Radiologic aspects of renovascular hypertension Part 2 The role of urography in unilateral renovascular disease J Amer med Ass 220 (1972) 1225

BROLIN B Renal artery changes in hypertension Acta radiol Diagnosis 6 (1967) 401

COLLIER R O and SWANN H G Relation of kidney size to blood pressure Amer J Physiol 220 (1971) 488

COUCH N P SULLIVAN J and CRANE CH The predictive accuracy of renal vein renin activity in the surgery of renovascular hypertension Surgery 79 (1976) 70

DAVIDSON A J and TALNER L B Critical analysis Lack of specificity of renal angiography in the diagnosis of renal parenchymal disease A point of view Invest Radiol 8 (1973) 90

DEAN R H BURKO H WILSON J P MULHERIN J H and FOSTER J H Deceptive patterns of renal artery stenosis Surgery 76 (1974) 872

DELIN N A EKESTRÖM S and HÖGLUND N O Arteriographic appearance of renal artery stenosis compared to resistance measured at operation Effect of artery reconstruction on flow pressure gradient and resistance Acta chir scand (1966) Suppl No 356 B p 150

DE VRIES H K and VAN DEN BERG J W On the origin of poststenotic dilatations Cardiologia 33 (1958) 195

DUSTAN P H HUMPHRIES A W DE WOLFE V G and PAGE I H Normal arterial pressure in patients with renal arterial stenosis J Amer med Ass 187 (1964) 1028

FROM THE DEPARTMENTS OF DIAGNOSTIC RADIOLOGY SURGERY AND ENDOCRINOLOGY
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UNILATERAL RENAL ARTERY STENOSIS AND HYPERTENSION

II Angiographic findings correlated with blood pressure response after surgery

I ANDERSSON S E BERGENTZ B F ERICSSON J F DYMLING
B G HANSSON and B HOKFELT

Modern reconstructive vascular surgery has made it possible to treat hypertension caused by renal artery stenosis or occlusion It is however evident that a considerable number of patients with hypertension and renal artery stenosis do not benefit from operation and that the proper selection of patients for surgery remains a problem (SHAPIRO et coll 1969 BERGENTZ et coll 1971 FOSTER et coll 1975 SHAPIRO et coll 1976 NORDHUS et coll 1978)

The demonstration of an increased plasma renin activity in venous blood from the kidney affected by stenosis or occlusion is widely relied upon as an indication of renovascular hypertension However this test producing a number of false positive and false negative results is not infallible (MARKS & MAXWELL 1975 COUCH et coll 1976 STONE et coll 1977)

Nephroangiography is the single most important method to demonstrate the presence of a renal artery stenosis However opinions differ on the role of angiography as a method to determine the functional significance of a stenosis BOOKSTEIN (1966) and BOOKSTEIN & WALTER (1975) considered nephroangiography a valuable method in this respect while DELIN et coll (1966) BROLIN (1967) MAXWELL et coll (1967) FOSTER et coll (1973) and JUNCOS et coll (1974) considered it to be of no or

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R D Measurement of renin in both renal veins Its use in diagnosis of renovascular hypertension Arch intern Med 120 (1967) 444
MOLLL H Kidney size and its deviation from normal in acute renal failure A roentgen diagnostic study Acta radiol (1961) Suppl No 206
REICH S B RILEY III J C CHRISTOPHER R A WALKER L A and EVERITT J H Changes in the pulse wave form with flow through vessels with repetitive saccular dilatations and stenosis Invest Radiol 10 (1975) 622
RODBARD S IKEDA K and MONTES M An analysis of mechanisms of poststenotic dilatation Angiology 18 (1967) 349
ROSENBUSCH G VAN DOUVEREN W PENN W M und THIJSSEN H Stenosen bei multiplen Nierenarterien und Ausbildung eines reno renalen Kollateralkreislaufs Fortschr Röntgenstr 120 (1974) 164
STOCKIGT J R COLLINS R D NOAKES C A SCHAMBELAN M and BIGLIERI E G Renal vein renin in various forms of renal hypertension Lancet 1 (1972) 1194
SUTTON D BRUNTON F J and STARER F Renal artery stenosis Clin Radiol 12 (1961) 80
THOMAS C S JR BROCKMAN S K and FOSTER J H Variability of the pressure gradient in renal artery stenosis Surg Gynec Obstet 126 (1968) 339
VERTES V GRAUEL J A and GOLDBLATT H Studies of patients with renal hypertension undergoing vascular surgery New Engl J Med 272 (1965) 186
VIDT D G YUTANI F M MCCORMACK L J GIFFORD R W STEWART B H MCLAUGHLIN TH C MEANY TH F and MCEVEN D A Surgical treatment of unilateral renal vascular disease Prognostic role of vascular changes in bilateral renal biopsies Amer J Cardiol 30 (1972) 827

tion as preoperatively and a reduction of at least 15 mmHg c) Diastolic blood pressure 110 mmHg or less with medication in patients with hypertension which was preoperatively refractory to antihypertensive treatment

Failure (a) A reduction of diastolic blood pressure less than 10 mmHg without medication (b) No reduction of diastolic blood pressure with the same medication as preoperatively (c) Diastolic blood pressure over 110 mmHg with medication

The blood pressure was measured in supine position after 15 min of rest by a trained nurse A mercury manometer was used Phase V of the Korotkoff sounds was taken for determination of the diastolic pressure

Renin assay was performed in 33 patients Blood samples were drawn from the renal veins after 15 min of tilting Antihypertensive drugs were withheld for at least 1 week before sampling A renal vein renin activity ratio (RVRR) was calculated as the renin activity in venous blood from the stenotic kidney over the nonstenotic one A ratio over 1 3 was considered to indicate renovascular hypertension The renin activity was determined by radioimmunoassay of angiotensin I (HABER et coll 1969)

Results

Thirty four patients were cured or improved 8 were unimproved It is evident from Table 2 that 32/38 (84) of the patients with either occlusion or a reduction of luminal area of 90 per cent or more were cured or improved (Figs 1 2) Of 4 patients with a reduction of luminal area between 75 and 90 per cent 2 were cured or improved one of these with only one kidney In the other patient a short zone of decreased attenuation was seen in the stenosis indicating a more severe constriction than was evident from the cranio caudal diameter

Collateral circulation was demonstrated in 24/42 patients (57) 22 of the 24 (9?) were cured or improved Also 12/18 (67) patients without collateral circulation were cured or improved

Poststenotic dilatation was demonstrated in 34/36 patients (94) occlusions excluded Of these 34 (76) 26 were cured or improved and 8 unimproved (24 %) Two patients without poststenotic dilatation were improved

Fifty per cent of the patients (20/40 two patients with only one kidney excluded) had a reduction of the kidney length of 1 cm or more 18 (90) were cured or improved Of 20 patients with a reduction of the kidney length less than 1 cm 14 (70 %) were cured or improved 10 of these had a stenosis or occlusion of one of multiple arteries or of a branch Another cured patient was a 6-year old child Thus of 14 cured or improved adult patients with a reduction of the kidney length less than 1 cm only 3 had a stenosis involving the main stem of a single artery A local reduction of the kidney parenchyma occurred in all but one of the patients with stenosis or occlusion engaging only part of the kidney Of 6 unimproved patients with a reduction of the kidney length less than 1 cm 4 had a stenosis in the main stem of a single artery

Table I

Surgical procedures (42 cases)

Reconstruction with autogenous vein graft from aorta	16
Thrombendarterectomy with or without patch	11
Reconstruction with patch	3
Reconstruction with autotransplantation to the iliac fossa	3
Resection and anastomosis end to end or reimplantation	4
Nephrectomy	3
Resection of the kidney	2

only limited value In Part I (ANDERSSON 1979) the preoperative angiographic findings in 43 patients with unilateral renal artery stenosis and suggested renovascular hypertension were described and the significance of these findings was discussed In the present report the angiographic findings are correlated to the blood pressure response after reconstructive surgery or nephrectomy in an attempt to define the angiographic characteristics of surgically curable renovascular hypertension

Material and Methods

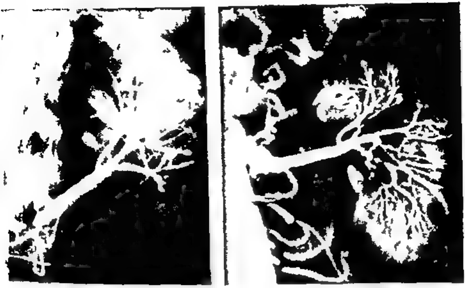
The material consisted of the same 43 patients as in Part I with unilateral renal artery stenosis or occlusion One patient was lost to follow up Thus 42 patients form the basis of the present report In 19 patients with a mean age of 51 years (range 42–69 years) the stenosis or occlusion was of atherosclerotic type in 13 patients (mean age 31 years range 5–40 years) the stenosis was caused by fibromuscular dysplasia and in 10 (mean age 38 years range 10–66 years) the stenosis was of other or not specified type

The factors recorded from the preoperative films and other details are given in Part I

The indication for operation was based on the findings at nephroangiography and in 33 of the patients also on determination of plasma renin activity in the renal venous blood The interval between angiography and operation varied between 5 and 365 days with a mean of 37 days The surgical procedures are listed in Table I Four patients were reoperated upon due to failure of the first operation In these cases the definite procedures were listed as were the results of the final operations The 42 patients were followed postoperatively for a mean of 28 months (range 7–58 months) Postoperative angiography was performed in 16 patients In the classification of the response to surgery the principles given by MAXWELL et coll (1972) were largely followed

Cure Diastolic blood pressure 90 mmHg or less without medication

Improvement a) Decrease in diastolic blood pressure with at least 15 mmHg without medication b) Diastolic blood pressure 90 mmHg or less with the same medica



a b

Fig 2 a) Preoperative angiography 49 year old man Atheromatous sclerosis in the renal artery reducing luminal area by 90 or more (→) No collateral circulation b) Angiography 2 weeks after thrombendarterectomy and reconstruction with vein patch Moderate dilatation corresponding to the patch Patient normotensive 4 years after operation

kidney supplied by the stenotic artery was unimproved while 3/6 patients with bi lateral lesions were unimproved (Table 3)

Of 74 30 patients (80) with an RVRR over 1 3 18 were cured and 6 improved 6 (20) were unimproved The remaining 3 patients had an RVRR of 1 3 or less and were cured or improved In 2 of these patients the vascular lesions engaged only part of the kidney while the third patient had a stenosis in the main stem of a sin le artery

Eight of 42 patients were unimproved and postoperative angiography was per

Table 3

Intra enal arterial lesions or cort cal lesions versus blood pressure response (37 patients)

	Lesions con fined to kid ney affected by stenosis	Lesions con fined to contralateral kidney	Bilateral lesions	No lesions
Cured	5		2	15
Improved	2	1	1	4
Unimproved	1	1	3	2
Total	8	~	6	21

a b

Fig. 1. a) Preoperative angiography. 32-year-old woman. Fibromuscular dysplasia in distal part of renal artery. Short stenosis reducing luminal area by 90 % or more. Collateral flow through inferior adrenal artery. Stenotic segment was resected and the renal artery reconstructed with an autologous vein graft. The patient became normotensive. b) Angiography 1 year after operation. Normal vein graft. No collaterals.

If only patients with a stenosis in the main stem of a single artery are considered 16/18 (89 %) with a reduction of the kidney length of at least 1 cm were cured or improved and 4/8 (50 %) with a reduction less than 1 cm.

Only 1/8 patients with intrarenal arterial lesions or cortical lesions confined to the

Table 2

Blood pressure response after surgery versus angiographic abnormalities in 42 patients with unilateral renal artery stenosis or occlusion

	Cured	Improved	Unimproved	Total
Occlusion	4	2		6
Reduction of lumen area by 90 % or more	20	6	6	32
Reduction of lumen area 75–90	1	1	2	4
Total	25	9	8	42
Collateral circulation +	17	5	2	24
Collateral circulation −	8	4	6	18
Poststenotic dilatation +	21	5	8	34
Poststenotic dilatation −		2		2
Reduction of kidney length 1 cm or more	14	4	2	20
Reduction of kidney length less than 1 cm	10	4	6	20

+ presence of lesion

− absence of lesion

Fig 4 Postoperative angiography 35-year-old woman Fibromuscular dysplasia engaging one of two right renal arteries The main stem of the affected artery was reconstructed with an autologous vein from the aorta (↔) Occluded branches could not be reconstructed and are supplied by collaterals (→) Blood pressure unimproved Cortex of upper pole of the kidney supplied by a normal artery irregular as was cortex of contralateral kidney possibly due to nephrosclerosis

Postoperative angiography was not performed in 2 unimproved patients with stenosis of not specified type Both had an RVRR over 1 3 The 2 patients in this series with the least severe stenoses reducing luminal area about 75 and 82 per cent respectively were both unimproved RVRR was positive in both cases

The results of operation in relation to the type of stenosis were as follows Of 11/13 patients with fibromuscular dysplasia (84°) 9 were cured and 2 improved of 15/19 patients with atherosclerosis (79) 11 were cured and 4 improved and of 8/10 patients with stenosis of other not specified type (80°) 5 were cured and 3 improved Two patients with fibromuscular dysplasia 4 with atherosclerosis and 2 with other types of stenosis were unimproved

Discussion

It is generally agreed that hypertension caused by a renal artery stenosis is mediated through the renin angiotensin system The mechanisms of renin release are complex Much attention has been drawn to the baroreceptor theory implying that the renin producing juxtaglomerular cells in the afferent arterioles act as stretch receptors (TOBIAN et coll 1959) There is evidence indicating that these receptors respond to changes in mean arterial pressure (SKINNER et coll 1964)

Previous clinical and experimental investigations have shown that the transverse area of a renal artery must be reduced 80 to 85 per cent to give a perceptible reduction of pressure and flow rate distal to the stenosis (HAIMOVICI & ZINICOLA 1962 MAY et coll 1963 BJORNO & PETTERSSON 1977) In the present series 38 patients had

b

b

Fig 3 Preoperative angiography 55 year old man Atheromatous stenosis in the renal artery reducing luminal area by 90 or more No collateral circulation b) Angiography 3 yea s after reconstruction of the artery with an autologous vein from the aorta Blood pressure unimproved despite normal graft The outlining of the kidney slightly irregular in the intermediate part Length of kidney reduced compared with preoperative angiography

formed in 6 of these Four patients (mean age 58 years) had a stenosis of athero sclerotic type 2 (29 and 35 years of age) fibromuscular dysplasia and 2 (44 and 47 years of age) a stenosis of not specified type Postoperative angiography of the 4 patients with atherosclerotic stenosis revealed a normal lumen in the reconstructed artery in 3 patients (Fig 3) and a slight stenosis in one In one of the patients a supplementary artery had become occluded since the preoperative examination All 4 patients had intrarenal arterial abnormalities or cortical lesions which were bilateral in 3 patients and confined to the kidney affected by stenosis in one patient This latter patient also had a local infarction of the kidney At postoperative examination (mean interval between pre and postoperative angiography 26 months) the kidneys had diminished in length bilaterally compared with the preoperative examination Preoperative RVRR was over 1 3 in 3 and not performed in one of the unimproved patients with atherosclerotic stenosis

One of the 2 unimproved patients with fibromuscular dysplasia was a technical failure At postoperative angiography branches of the renal artery were occluded and supplied by collaterals (Fig 4) In the other patient (RVRR over 1 3) the operation was technically adequate but a severe poststenotic dilatation remained post operatively (Fig 5)

influence the measurement of a stenosis which then can be underestimated Such factors might at least in part explain the results of the Cooperative Study

The importance of collateral circulation as an indication of curable renovascular hypertension proposed by other authors (BOOKSTEIN BROLIN ERNST et coll 1972 BOOKSTEIN & WALTER) is confirmed in the present series If one technical failure is excluded all patients but one (22/23) with collateral circulation were cured or improved On the other hand absence of collateral circulation does not mean an insignificant stenosis which is illustrated by 12 cured or improved patients of 18 without collateral circulation Possible explanations were discussed previously (Part I ANDERSSON)

In the present material poststenotic dilatation was present in all but 2 of the patients with a reduction of lumen area of at least 90 per cent and in all 4 patients with less severe stenosis BOOKSTEIN et coll (1972) found poststenotic dilatation in 13 per cent of patients with stenosis reducing luminal diameter by less than 50 per cent and SUTTON et coll (1961) observed poststenotic dilatation in 9 of 20 stenoses with 50 per cent reduction of luminal diameter It thus seems probable that poststenotic dilatation may be generated by stenoses which should be insignificant in regard to renovascular hypertension

A reduction of the size of a kidney may be caused by a variety of lesions However in cases of hemodynamically significant renal artery stenosis such a reduction of the kidney size may be due to a fall in blood pressure (COLLIER & SWANN 1971) Also ischemic atrophy which is a common finding in kidneys supplied by stenotic arteries (CONNOR et coll 1957) may play a role This is corroborated by the increase in size of the kidney noted on angiography after successful arterial reconstructions The present results indicate that the majority of significant stenoses engaging the main stem of a single artery reduced the kidney length by at least 1 cm If the stenosis or occlusion engaged only part of the kidney the reduction of the length of the kidney was less than 1 cm in the majority of cases

From the present material it appears that ipsilateral intrarenal arterial or cortical lesions in most cases do not preclude a favorable response to surgery On the contrary bilateral lesions in combination with a stenosis of atherosclerotic type probably implies a worse prognosis These cases probably represent a more advanced atheromatous disease The mean age of these patients was higher than that of the whole group of patients with atheromatous stenosis Two patients with lesions confined to the contralateral kidney one of whom was a technical failure do not permit any conclusions

An RVRR over 1 3 correctly predicted a favorable response to surgery in 24/30 patients (80) Six patients with RVRR over 1 3 were unimproved thus representing false positives Three patients with RVRR of 1 3 or less were cured or improved thus representing false negatives An RVRR over 1 3 may occur in various renal parenchymal diseases and also in patients with essential hypertension (MARKS & MAXWELL STONE et coll) A false negative RVRR may be caused by various factors

a

b

Fig 5 a) Preoperative angiography 29 year old woman Short stenosis in renal artery reducing luminal area by more than 90 (→) Severe poststenotic dilatation b) Angiography 3 years after reconstruction with patch graft Remaining dilatation Blood pressure unimproved

either occlusion of the renal artery or a stenosis reducing the area by 90 per cent or more Thirty two of these patients were cured or improved by surgery Only 4 patients had a stenosis reducing the luminal area by 75 to 90 per cent one was cured one improved and 2 unimproved The patient who was cured had only one kidney In such a case a smaller degree of stenosis may be critical due to increased volumetric flow rate

The results are in accordance with those of BOOKSTEIN who found that main stem stenoses with a diameter of 1 5 mm or less always were hemodynamically significant and that stenoses with a diameter of 1 6 to 3 mm in half of the cases were significant About 75 per cent of significant stenoses had a favorable response to surgery However, in the Cooperative Study of Renovascular Hypertension (BOOKSTEIN et coll 1972) a favorable response to surgery was achieved not only in 148/196 patients (76 %) with a reduction of luminal diameter of over 50 per cent (which means a reduction of luminal area of over 75 % assuming the lumina to be annular) but also in 19/32 patients (59 %) with a reduction of luminal diameter of less than 50 per cent These results are difficult to explain in view of the data on the degree of stenosis necessary to produce a decrease in pressure and volumetric flow rate As was pointed out previously (Part I ANDERSSON) projectional and technical factors

ZUSAMMENFASSUNG

Die Befunde bei einer praoperativen Nephroangiographie von 42 hypertonischen Patienten mit unilateraler renaler arterieller Stenose bzw Okklusion wurden zu der Blutdruckveränderung im Anschluss an die Chirurgie und ebenfalls zum praoperativen renalen venosen Reninaktivitat Verhaltnis korreliert Eine Stenose die den Querschnitt von mindesten 90 Prozent einschrankt (oder Okklusion) und das Vorkommen einer kollateralen Zirkulationen wurden als stark verdachtig fur eine renovaskulare Hypertension befunden

RÉSUME

Les auteurs ont etabli une correlation entre les signes néphroangiographiques préopératoires chez 42 malades hypertendus ayant une stenose ou une occlusion unilaterale de l artere renale et la réponse de la pression artérielle après l intervention chirurgicale et aussi le rapport d activite de la rénine avant l operation dans la veine rénale Une sténose réduisant la surface de la lumière arterielle d au moins 90 (ou une occlusion) et la présence d une circulation collatérale sont considérees comme des signes de forte présomption d hypertension rénovasculaire

REFERENCES

ANDERSSON I Unilateral renal artery stenosis and hypertension I Angiography Acta radiol Diagnosis 20 (1979) 878

BERGENTZ S E KJELLBO H and HOOD B Renal artery stenosis Prog Surg 9 (1971) 1

BJORNO L and PETTERSSON H Hydro and hemodynamic effects of catheterization of vessels V Experimental and clinical catheterization of stenoses Acta radiol Diagnosis 18 (1977) 193

BOOKSTEIN J J Appraisal of arteriography in estimating the hemodynamic significance of renal artery stenosis Invest Radiol 1 (1966) 281

— and WALTER J F The role of abdominal radiography in hypertension secondary to renal or adrenal disease Med Clin N Amer 59 (1975) 169

— ABRAMS H L BUENGER R E REISS M D LECKY J W FRANKLIN S S BLEIFER K H VARADY P D and MAXWELL M H Radiologic aspects of renovascular hypertension Part 3 Appraisal of arteriography J Amer med Ass 221 (1972) 368

BROLIN I Renal artery changes in hypertension Acta radiol Diagnosis 6 (1967) 401

COLLIER R O and SWAHN H G Relation of kidney size to blood pressure Amer J Physiol 220 (1971) 488

CONNOR T B BERTHRONG M THOMAS JR W C and HOWARD J E Hypertension due to unilateral renal disease—with a report on a functional test helpful in diagnosis Bull Johns Hopk Hosp 100 (1957) 241

COUCH N P SULLIVAN J and CRANE CH The predictive accuracy of renal vein renin activity in the surgery of renovascular hypertension Surgery 79 (1976) 70

DELIN N A EKESTRÖM S and HÖGLUND N O Arteriographic appearance of renal artery stenosis compared to resistance measured at operation Effect of artery reconstruction on flow pressure gradient and resistance Acta chir scand (1966) Suppl No 356 B 150

ERNST C B BOOKSTEIN J J MONTIE J BAUMGARTEL E HOOBLER S W and FRY W J Renal vein renin ratios and collateral vessels in renovascular hypertension Arch Surg 104 (1972) 496

(MARKS & MAXWELL) If the stenosis affects only a part of the kidney the renin activity may not be high enough in the main renal vein from which blood is usually sampled to give a significant ratio Two of the present cases may have this explanation The third patient had a stenosis in the main stem of a single artery

The results may be considered as follows A stenosis reducing luminal area by 90 per cent or more which usually means a diameter of stenosis of less than 2 mm in the main stem of an artery supplying a whole kidney strongly suggests a significant stenosis i e , a stenosis which is responsible for hypertension No definite conclusions can be drawn from the present material concerning stenoses reducing luminal area by 80 to 90 per cent but apparently also such stenoses may sometimes cause hypertension The possibility of the lumen not being annular should be kept in mind Collateral circulation is strongly suggestive of a significant stenosis A reduction of luminal area of 90 per cent or more and the presence of collateral circulation are the main criteria and are considered highly indicative one by one Although less specific abnormalities a reduction of kidney size and poststenotic dilatation may speak in favor of a significant stenosis they may be of value in cases which cannot be definitely evaluated on the basis of the main criteria

With the above criteria 6 unimproved patients with a stenosis reducing luminal area by 90 per cent or more were false positives (14 %) Four of these had renin determinations all with RVRR over 1 3 Two patients with a stenosis reducing luminal area by less than 90 per cent and with a favorable response to surgery were false negatives (5 %) One of these was correctly predicted by an RVRR over 1 3 It is thus apparent that within the group of patients with the most severe stenoses which were with all probability hemodynamically significant neither nephroangiography nor RVRR could with certainty differentiate those patients who would benefit from operation from those who would not Factors other than hemodynamic significance such as the presence of nephrosclerosis and the age of the patients may be of importance

Conclusion

No ideal method exists which can predict the blood pressure response after reconstructive surgery or nephrectomy for renal artery stenosis or occlusion The present series indicates that nephroangiography is a valuable method and that it is well comparable with the renal vein renin activity ratio as a predictive test The methods are complementary

SUMMARY

The findings at preoperative nephroangiography of 42 hypertensive patients with unilateral renal artery stenosis or occlusion were correlated with the blood pressure response following surgery and also with the preoperative renal vein renin activity ratio A stenosis reducing luminal area by at least 90 per cent (or occlusion) and the presence of collateral circulation are considered to be *highly suggestive of renovascular hypertension*

ZUSAMMENFASSUNG

Die Befunde bei einer präoperativen Nephroangiographie von 42 hypertonischen Patienten mit unilateraler renaler arterieller Stenose bzw Okklusion wurden zu der Blutdruckveränderung im Anschluss an die Chirurgie und ebenfalls zum präoperativen renalen venösen Reninaktivität Verhältnis korreliert Eine Stenose die den Querschnitt von mindesten 90 Prozent einschränkt (oder Okklusion) und das Vorkommen einer kollateralen Zirkulationen wurden als stark verdächtig für eine renovaskulare Hypertension befunden

RESUME

Les auteurs ont établi une corrélation entre les signes nephroangiographiques préopératoires chez 42 malades hypertendus ayant une stenose ou une occlusion unilaterale de l'artère rénale et la réponse de la pression artérielle après l'intervention chirurgicale et aussi le rapport d'activité de la rénine avant l'opération dans la veine rénale Une sténose réduisant la surface de la lumière artérielle d'au moins 90° (ou une occlusion) et la présence d'une circulation collatérale sont considérées comme des signes de forte présomption d'hypertension renovasculaire

REFERENCES

ANDERSSON I Unilateral renal artery stenosis and hypertension I, Angiography Acta radiol Diagnosis 20 (1979) 878

BERGENTZ S E KJELLBO H and HOOD B: Renal artery stenosis Prog Surg 9 (1971) 1

BJORNO L and PETTERSSON H Hydro- and hemodynamic effects of catheterization of vessels V Experimental and clinical catheterization of stenoses Acta radiol Diagnosis 18 (1977) 193

BOOKSTEIN J J Appraisal of arteriography in estimating the hemodynamic significance of renal artery stenosis Invest Radiol 1 (1966) 281

— and WALTER J F The role of abdominal radiography in hypertension secondary to renal or adrenal disease Med Clin N Amer 59 (1975) 169

— ABRAMS H L BUENGER R E REISS M D LECKY J W FRANKLIN S S BLEIFER K H VARADY P D and MAXWELL M H Radiologic aspects of renovascular hypertension Part 3 Appraisal of arteriography J Amer med Ass 221 (1972) 368

BROWN J Renal artery changes in hypertension Acta radiol Diagnosis 6 (1967) 401

COLLIER R O and SWAHN H G Relation of kidney size to blood pressure Amer J Phys ol 2 0 (1971) 488

CONNOR T B BERTHRONG M THOMAS JR W C and HOWARD J E Hypertension due to unilateral renal disease— with a report on a functional test helpful in diagnosi Bull Johns Hopk Hosp 100 (1957) 241

COUCH N P SULLIVAN J and CRANE CH The predictive accuracy of renal vein renin activity in the surgery of renovascular hypertension Surgery 79 (1976) 70

DEAN N A EKESTRÖM S and HOGLUND N O Arteriographic appearance of renal artery stenosis compared to resistance measured at operation Effect of artery reconstruction on flow pressure gradient and resistance Acta chir scand (1966) Suppl No 356 B 150

ERNST C B BOOKSTEIN J J MONTIE J BAUMGARTEL E HOOBLER S W and FRY W J Renal vein renin ratios and collateral vessels in renovascular hypertension Arch Surg 104 (1972) 496

FOSTER J H DEAN R H PINKERTON J A and RHAMY R K Ten years experience with the surgical management of renovascular hypertension Ann Surg 177 (1973) 755
— MAXWELL M H FRANKLIN S [redacted] BLEIFER K H, TRIPPEL O H JULIAN O C DECAMP P T and VARADY P T Renovascular occlusive disease Results of operative treatment J Amer med Ass 231 (1975) 1043
HABER E KOERNER TH PAGE L [redacted] KLIMAN B and PURNODE A Application of a radioimmunoassay for angiotensin I to the physiologic measurements of plasma renin activity in normal human subjects J clin Endocr 29 (1969) 1349
HAIMOVICI H and ZINICOLA N Experimental renal artery stenosis Diagnostic significance of arterial hemodynamics J cardiovasc Surg 3 (1962) 259
JUNCOS L I STRONG C G and HUNT J C Prediction of results of surgery for renal and renovascular hypertension Arch intern Med 134 (1974) 655
MARKS L [redacted] and MAXWELL M H Renal vein renin Value and limitations in the pred c tion of operative results Urol Clin N Amer 2 (1975) 311
MAXWELL M H LUPU A N and FRANKLIN S S Clinical and physiological factors determining diagnosis and choice of treatment of renovascular hypertension Circulat Res 20 and 21 (1967) Suppl No II p 201
— BLEIFER K H FRANKLIN S S and VARADY P D Cooperative study of renovascular hypertension Demographic analysis of the study J Amer med Ass 220 (1972) 1195
MAY A G VAN DEN BERG L DEVEESE J A and ROB CH G Critical arterial stenosis Surgery 54 (1963) 250
NORDHUS O EKESTRÖM S LILJEQUIST L and TIDGREN [redacted] Renal artery reconstruction in renovascular hypetension Scand J thorac cardiovasc Surg 12 (1978) 111
SHAPIRO A P MCDONALD R H and SCHEIB E Renal arterial stenosis and hypertension II Current criteria for surgery Amer J Cardiol 37 (1976) 1065
— PEREZ STABLE E SCHEIB E T BRON K MOUTSOS S E BERG G and MISAGE J R with the assistance of BANSON H FISHER [redacted] and DRAPANAS TH Renal artery stenosis and hypertension Observations on current status of therapy from a study of 115 patients Amer J Med 47 (1969) 175
SKINNER S L MCCUBBIN J W and PAGE I H Control of renin secretion Circulat Res 15 (1964) 64
STONE R A TALNER L [redacted] and COEL M N Renal vein renin activity in primary hypertension Variability and influence of contrast material Invest Radiol 12 (1977) 455
SUTTON D BRUNTON F J and STARER F Renal artery stenosis Clin Radiol 12 (1961) 80
TOBIAN L TOMBOULIAN A and JANECEK J The effect of high perfusion pressures on the granulation of juxtaglomerular cells in an isolated kidney J clin Invest 38 (1959) 605

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PERCUTANEOUS PRODUCTION OF RENAL ARTERY LESIONS

Experiments in the pig

L EKELUND and H STRIDBECK

Most experimental techniques that have been used to produce renal artery stenosis require surgical exploration of the renal artery Recently a non surgical percutaneous technique using guide wire manipulation of the renal artery has been described (EKELUND et coll 1978) The risk of total occlusion and clot formation in the renal artery after subintimal injection is considered high (JONSSON et coll 1977) but clinical experience of the natural course of these lesions is limited Therefore it was found motivated to investigate in an experimental model the sequelae of various types of intraarterial injury to the renal artery

Material and Methods

Four mixed breed domestic swine weighing 6 to 8 kg at the beginning of the ex perimental period were used General anaesthesia was provided by an initial dose of 100 mg ketaminum (Ketalar Parke Davis U S A) and 10 mg droperidolum (Dridol Leo Sweden) given intramuscularly The anaesthesia was supplemented when needed with the same drugs intravenously The femoral artery was exposed and a red thin walled Kifa catheter (OD/ID 2 2/1 45 mm) with a curved tip was introduced into the artery Intraarterial blood pressure was recorded and abdominal aortography was then performed using 15 ml of Isopaque Cerebral (Nyegaard Oslo Norway) in

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Fig. 1. a) Extravasation of contrast medium following traumatization of the right renal artery. b) Intimal tear in artery supplying upper pole of left kidney. c) 5 days later a stenosis has developed. Emboli in arteries supplying lower pole. d) Immediately following balloon catheter dilatation stenosed segment has somewhat increased diameter.

Fig. 2. Same case as Fig. 1. Angiography 20 days following arterial dilatation. Occlusion of previously stenosed artery on left side. Persistent aneurysm in main stem of right renal artery (→).

jected at a rate of 15 ml/s. One film was exposed per second for 6 seconds. The renal arteries were then selectively catheterized, a metal guide wire introduced and the stiff end passed beyond the tip of the catheter in the renal artery. Thereafter the intima of the renal artery was injured by vigorous manipulation of the guide wire. After this procedure angiography was performed in order to document the immediate effect of this mechanical injury to the renal artery. For the selective series 4 ml of contrast medium were used, injected at a rate of 5 ml/s. The same procedure was performed on both sides. The catheter was then withdrawn, the femoral artery sutured, hemostasis obtained and the animal was returned to its quarters. Repeat catheterization (from the contralateral femoral artery) was carried out within 4 to 45 days, the blood pressure was recorded and subsequent abdominal aortography and selective angiography of the kidneys were performed. A 5 French (OD 1.7 mm) balloon catheter (Meditech, Cooper Scientific Corporation, U.S.A.) was then introduced and the balloon inflated for 30 s with 1 to 3 ml of contrast medium in 4 separate renal arteries (2 with stenoses). When the immediate effect of the balloon distension had been recorded at repeat angiography the catheter was withdrawn and the animal allowed to recover. Within 18 to 43 days repeat catheterization (via the left carotid or axillary artery) was performed and the blood pressure recorded, followed by angiography.

Results

A survey of the angiographic findings is given in the Table. Vigorous manipulation of the tip of the guide wire resulted in rupture of the right renal artery in one case

Table

Angiographic findings in the present material

Animal No	Immediate effect of manipulation	Time interval (days)	Second catheterization	Time interval (days)	Third catheterization
1	Extravasation right intimal lesion left	5	Aneurysm right segmental artery stenosis left balloon dilatation	20	Aneurysm right occlusion left segmental artery
2	Intimal lesions bilaterally	45	Intimal lesions healed balloon over distended left renal artery → pseudoaneurysm	43	Regression of pseudoaneurysm
3	Intimal lesions bilaterally	27	Intimal lesions healed balloon over distended left renal artery → rupture	19	Severe stenosis left renal artery
4	Intimal lesion right	20	Stenosis right renal artery balloon dilatation	18	Occlusion right renal artery

with extravasation of contrast medium An intimal lesion was produced in a segmental artery on the contralateral side At repeat angiography after 5 days the ruptured right renal artery had healed with an aneurysm as sequela and a segmental renal artery stenosis was demonstrated on the left side Balloon catheter dilatation was attempted within this stenosed segmental artery but repeat angiography 20 days later showed this artery to be occluded The aneurysm of the right renal artery was persistent (Figs 1 2)

In the second pig bilateral intimal lesions were created These lesions had healed 45 days later (Fig 3 a b) The balloon was then over distended (inflated with 3 ml of contrast medium) in the left renal artery resulting in the production of a pseudo aneurysm The size of the aneurysm had remarkedly decreased 43 days later (Fig 3 c, d)

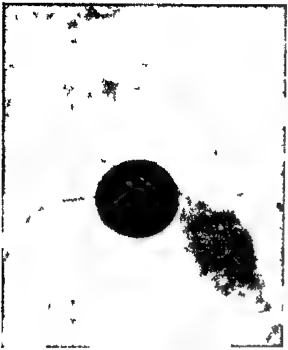
Bilateral intimal lesions were also produced in the third animal Even these lesions were healed at angiography 27 days later A balloon catheter was then introduced and the balloon over distended in the left renal artery, resulting in rupture of the artery (Fig 4 a, b) The pig survived after treatment with intraarterial fluid and 19 days later was a severe stenosis of the artery demonstrated as a result of the previous rupture (Fig 4)

The last animal in the series had an intimal lesion of the right renal artery while no effect of the guide wire manipulation could be traced in the contralateral artery A stenosis of the injured artery was demonstrated 20 days later and the kidney had

Fig. 3 a) Intimal lesion in main stem of left renal artery. (Intimal tear was evident in right renal artery as well.) b) Abdominal aortography 45 days later. Healing of intimal lesions bilaterally. c) Nephroangiography immediately following over-distension of balloon in left renal artery demonstrating large pseudoaneurysm. d) 43 days later. Surprisingly rapid decrease in size of pseudoaneurysm. (Catheterization via left carotid artery.)

decreased considerably in size. An attempt was made to dilate this stenosis with balloon catheter (inflated with 1 ml of contrast medium) but 18 days later the artery was found to be occluded (Fig. 5).

Guide wire manipulation thus led to intimal lesions in 7 of 8 renal arteries (including one case of extravasation). Healing, as estimated at angiography, had occurred in 4 of these renal arteries 27 and 45 days later. Stenotic lesions were produced in 2 arteries and an aneurysm in one. Balloon catheter dilatation of the 2 stenotic



a

b

Fig 4 a) Balloon over distended in left renal artery resulting in b) rupture and marked extra vasation of contrast medium c) 19 days later severe stenosis of previously ruptured left renal artery

c

lesions resulted in occlusion in both instances Over distension of the balloon resulted in pseudoaneurysm formation in one case and renal artery rupture in the other No significant change in blood pressure occurred in any of the animals during the ex perimental period

b

b

c

d

e

Fig 5 a) Intimal lesion of main stem of right renal artery immediately following guide wire manipulation b) Abdominal aortography 20 days later Severe stenosis of right renal artery with shrunken kidney (→). c) Balloon inflated in stenosed renal artery d) Immediately following balloon catheter dilatation stenosis is less marked Accumulation of contrast medium within contracted kidney e) Abdominal aortography 18 days following dilatation (catheter via left axillary artery) Total occlusion of right renal artery

a

b

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c

d

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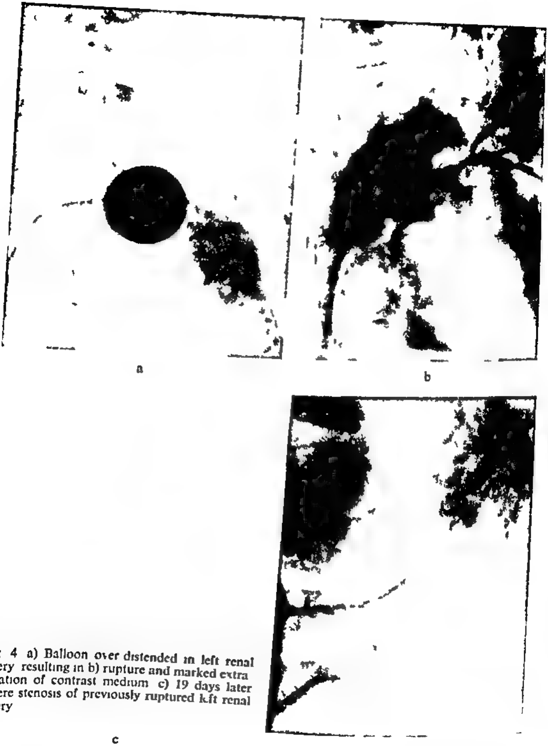

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slightly after 2 weeks No repeat angiography was performed The same technique was attempted in the present 2 cases of experimental renal artery stenosis The immediate effect of dilatation as evaluated at angiography looked promising (increased diameter of the stenosed artery) but repeat aortography after 18 and 20 days respectively showed complete occlusion of the stenosed artery In both instances were the stenoses of the elongated type which probably is not well suited for balloon dilatation short, membraneous stenoses are probably more prone to react positively Certainly further experiences of this technique in experimental models are necessary before general use in clinical practice

Possible complications from over-distension of the balloon in the renal artery were also investigated Previous experiments with balloon catheters in angiography have suggested that undue distension of the balloon may cause aneurysm or rupture (JENSEN & OLIN 1972) In the present series both these types of complications could be produced by overinflating the balloon with 3 ml of contrast medium (Figs 4 5) The traumatic pseudoaneurysm regressed remarkably over a period of 43 days but still represents a serious complication that must be taken into consideration in a discussion of the indications for the use of balloon catheters in diagnostic and therapeutic angiography However as pointed out by JENSEN & OLIN if the balloon is over-distended its shape will change from a sphere to a cylinder which is easily revealed at fluoroscopy The risk of complication should also decrease by the use of the type of balloon catheter recently introduced by GRÜNTZIG et coll

A possible further application of the present percutaneous experimental technique of injuring the intima of the renal artery by guide wire manipulation includes an analysis of etiologic factors in atherogenesis It has thus been shown in rabbit experiments that mechanical trauma to the aorta may produce lipid rich non regressive intimal thickening suggesting trauma as possible initial factor in atherogenesis (BJÖRKERUD 1969) The present technique in combination with microscopic examination of the injured renal artery might provide further information regarding the development of atheromatous renal artery stenosis and subsequent renal vascular hypertension

SUMMARY

Percutaneous intraarterial traumatization of both renal arteries in 4 pigs using the stiff end of a guide wire resulted in intimal lesions in 7 arteries At repeat angiography healing was demonstrated in 4 of these arteries suggesting that spontaneous restitution may be more common than usually believed Balloon catheter dilatation of 2 stenotic segments initially increased the diameter of the stenoses but at repeat angiography both arteries were found to be occluded Over-distension of the balloon in the renal artery resulted in pseudoaneurysm in one case and rupture in the other

ZUSAMMENFASSUNG

Die perkutane intraarterielle Traumatisierung beider renaler Arterien von 4 Schweinen unter Verwendung des steifen Endes eines Leiter Drahtes fuhrte zu einer Intima Läsion

Discussion

Most experimental techniques for the production of renal artery stenosis require surgical exploration of the renal artery Clamps constrictors and various degrees of ligature of the renal artery have been used (GOLDBLATT et coll 1934 HAIMOVICI & ZINICOLA 1962, FERRARIO et coll 1971 LUPER et coll 1972) The deposition of a piece of catheter within the renal artery with subsequent thrombus formation has also been used to initiate progressive stenosis and subsequent occlusion (HELLSTEN et coll 1976) Recently a non surgical percutaneous and intraarterial technique for creation of renal artery stenosis in the dog was reported (EKELUND et coll) Using this technique with guide wire manipulation of the renal artery, intimal lesions were produced in 7 of 8 renal arteries in the present series These lesions usually had the same radiographic appearance as the intimal tears occasionally seen in clinical angiography JONSSON et coll (1977) found subintimal deposits of contrast medium in 5 (0 9 %) renal arteries at 583 nephroangiographies These authors concluded that the risk of total occlusion and clot formation in the renal artery after subintimal injection is high TALNER et coll (1975) reported 3 cases of renal artery dissection as a complication of catheter angiography They concluded that dissection causing complete vascular obstruction usually requires immediate surgery although spontaneous re establishment of flow may occur They also pointed out the fact that if a subintimal injection is observed fluoroscopically during the test injection further injections of contrast medium should be avoided as each injection increases the likelihood of vascular occlusion The fact that 4 of 7 intimal tears in the present series healed would seem to indicate a tendency for spontaneous restitution in cases where the obstruction of renal blood flow is not significant KADIR (1978) observed spontaneous healing of catheter induced intimal lesions of renal arteries in 2 patients However it should be emphasized that the atheromatous lesions occurring in older patients but not in the experimental animal certainly play an important role in the natural history of these intimal lesions providing a higher risk for clotting and subsequent occlusion

Using the present technique of mechanical injury to the intima stenotic lesions developed in 2 of 8 renal arteries In one case (Fig 5) the stenosis was undoubtedly hemodynamically significant as the size of the kidney decreased considerably within 20 days Therefore it is surprising that no significant change in blood pressure could be detected in any of the animals The fact that the blood pressure recordings were obtained during general anaesthesia may be of some relevance in this connection

Recently a preliminary report on balloon catheter dilatation of renal artery stenosis in the dog was published and the possible clinical indications of this technique discussed (EKELUND et coll 1978) The same year a percutaneous transluminal dilatation of a renal artery stenosis in a 61 year old patient with hypertension was reported by GRÜNTZIG et coll Shortly after balloon catheter dilatation blood pressure was normalized and renal plasma flow increased However, blood pressure increased

slightly after 2 weeks No repeat angiography was performed The same technique was attempted in the present 2 cases of experimental renal artery stenosis The immediate effect of dilatation as evaluated at angiography looked promising (increased diameter of the stenosed artery) but repeat aortography after 18 and 20 days respectively showed complete occlusion of the stenosed artery In both instances were the stenoses of the elongated type which probably is not well suited for balloon dilatation short membraneous stenoses are probably more prone to react positively Certainly further experiences of this technique in experimental models are necessary before general use in clinical practice

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von 7 Arterien Bei wiederholter Angiographie wurde eine Abheilung in 4 dieser Arterien nachgewiesen was zur Vermutung führt dass eine spontane Restitution gewohnlicher, als bisher angenommen wird ist Eine Ballonkatheter Dilatation von 2 stenotischen Segmenten vergrosserte initial den Diameter der Stenosen, bei wiederholter Angiographie waren jedoch beide Arterien okkludiert Eine Überdehnung des Ballons in der renalen Arterie führte zu einem Pseudoaneurysma in einem Fall und Ruptur in einem anderen

RÉSUMÉ

Le traumatisme intraarteriel par voie percutanée des 2 artères rénales réalisé sur 4 porcs au moyen de l extrémité rigide d un guide métallique a donné des lésions de l intima dans 7 artères Une deuxième angiographie a montré la guérison de ces lésions dans 4 de ces artères faisant penser que la restitution spontanée peut etre plus fréquente qu on ne le croit habituellement La dilatation par un cathéter à ballonnet de 2 segments artériels sténosés a d abord augmenté le diamètre des sténoses mais une angiographie ultérieure a montré que les 2 artères étaient occluses La surdistension du ballonet dans l artère rénale a donné un pseudoanévrysme dans un cas et une rupture dans l autre

REFERENCES

BJÖRKERUD S Atherosclerosis initiated by mechanical trauma in normolipidemic rabbits J atheroscler Res 9 (1969) 209

EKELUND L GERLOCK JR J GONCHARENKO V and NOVAK G Balloon catheter dilatation of renal artery stenosis in the dog A preliminary report Europ Urol 4 (1978) 298

FERRARIO C M BLUMLE C NADZAM G R and McUBBINS J W An externally adjustable renal artery clamp J appl Physiol 31 (1971) 635

GOLDBLATT H LYNCH J HANZAL R and SUMMERVILLE W W Studies on experimental hypertension The production of persistent elevation of systolic blood pressure by means of renal ischemia J exp Med 59 (1934) 347

GRÜNTZIG A VETTER W MEIER B KUHLMANN U LUTOLF U and SIEGENTHALER W Treatment of renovascular hypertension with percutaneous transluminal dilatation of a renal artery stenosis Lancet I (1978) 801

HAIMOVICI H and ZINICOLA N Experimental renal artery stenosis Diagnostic significance of arterial hemodynamics J cardiovasc Surg 3 (1962) 259

HELLSTEN S NYLANDER G and WULFF K A percutaneous intraarterial technique for producing renal artery stenosis Acta chir scand 142 (1976) 375

JENSEN R and OLIN T Balloon catheters in angiography An experimental investigation in rabbits Acta radiol Diagnosis 12 (1972) 721

JONSSON K LUNDERQUIST A PETTERSSON H and SIGSTEDT B Subintimal injection of contrast medium as a complication of selective abdominal angiography Acta radiol Diagnosis 18 (1977) 55

KADIR S Personal communication 1978

LUPER A N MAXWELL M H KAUFMAN J J and WHITE F W Experimental unilateral renal artery constriction in the dog Circulat Res 15 (1972) 567

TALNER L B McLAUGHLIN A P and BOOKSTEIN J J Renal artery dissection A complication of catheter arteriography Radiology 117 (1975) 291

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ARTERIAL ANATOMY IN THE NORMAL LARYNX AND IN LARYNGEAL CARCINOMA

Radiography of specimens

H SÖKJER and J OLOFSSON

The examination of laryngeal carcinoma by laryngoscopy palpation and radiography—conventional film examination tomography and laryngography—can usually provide adequate information on the superficial extent of the tumour (OLOFSSON & SÖKJER 1977 1979) Vocal cord fixation and radiographic evidence of cartilage destruction indicate deep tumour invasion but do not provide a sufficiently precise basis for deciding on the most suitable form of treatment in particular on the selection of patients for partial surgery with conservation of voice and airway Therefore it was considered of interest to elucidate whether the application of angiography could improve the radiologic evaluation of laryngeal carcinoma For this purpose angiography of normal and some pathologic specimens was performed and the results are now reported

The larynx is supplied by the superior and inferior laryngeal arteries which are branches of the superior and inferior thyroid arteries respectively (RAUBER KOPSCH 1955) The superior laryngeal artery usually enters the larynx through the thyrohyoid membrane but may enter through the thyroid foramen in the posterior upper part of the thyroid cartilage This was found to be the case in about 20 per cent

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RÉSUME

Le traumatisme intraartériel par voie percutanée des 2 artères rénales réalisé sur 4 porcs au moyen de l extrémité rigide d un guide métallique a donné des lésions de l intima dans 7 artères Une deuxième angiographie a montré la guérison de ces lésions dans 4 de ces artères faisant penser que la restitution spontanée peut etre plus fréquente qu on ne le croit habituellement La dilatation par un cathéter à ballonnet de 2 segments artériels sténosés a d abord augmenté le diamètre des sténoses mais une angiographie ultérieure a montré que les 2 artères étaient occluses La surdistension du ballonet dans l artère rénale a donné un pseudoanévrysme dans un cas et une rupture dans l autre

REFERENCES

BJÖRKERUD S Atherosclerosis initiated by mechanical trauma in normolipidemic rabbits J atheroscler Res 9 (1969) 209

EKELUND L GERLOCK JR J GONCHARENKO V and NOVAK G Balloon catheter dilatation of renal artery stenosis in the dog A preliminary report Europ Urol 4 (1978) 298

FERRARIO C M BLUMLE C NADZAM G E and MCUBBINS J W An externally adjustable *renal artery clamp J appl Physiol 31 (1971) 635*

GOLDBLATT H LYNCH J HANZAL R and SUMMERVILLE W W Studies on experimental hypertension The production of persistent elevation of systolic blood pressure by means of renal ischemia J exp Med 59 (1934) 347

GRÜNTZIG A VETTER W MEIER B KUHLMANN U LUTOLF U and SIEGENTHALER W Treatment of renovascular hypertension with percutaneous transluminal dilatation of a renal artery stenosis Lancet I (1978) 801

HAIMOVICI H and ZINICOLA N Experimental renal artery stenosis Diagnostic significance *of arterial hemodynamics J cardiovasc Surg 3 (1962) 259*

HELLSTEN S NYLANDER G and WULFF K A percutaneous intraarterial technique for producing renal artery stenosis Acta chir scand 142 (1976) 375

JENSEN R and OLIN T Balloon catheters in angiography An experimental investigation in rabbits Acta radiol Diagnosis 12 (1972) 721

JONSSON K LUNDERQUIST A PETTERSSON H and SIOSTEDT B Subintimal injection of contrast medium as a complication of selective abdominal angiography Acta radiol Diagnosis 18 (1977) 55

KADIR S *Personal communication 1978*

LUPER A N, MAXWELL M H KAUFMAN J J and WHITE F W Experimental unilateral renal artery constriction in the dog Circulat Res 15 (1972) 567

TALNER L B MCLAUGHLIN A P and BOOKSTEIN J J Renal artery dissection A complication of catheter arteriography Radiology 117 (1975) 291

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ARTERIAL ANATOMY IN THE NORMAL LARYNX AND IN LARYNGEAL CARCINOMA

Radiography of specimens

H SÖKJER and J OLOFSSON

The examination of laryngeal carcinoma by laryngoscopy palpation and radiography—conventional film examination tomography and laryngography—can usually provide adequate information on the superficial extent of the tumour (OLOFSSON & SÖKJER 1977 1979) Vocal cord fixation and radiographic evidence of cartilage destruction indicate deep tumour invasion but do not provide a sufficiently precise basis for deciding on the most suitable form of treatment in particular on the selection of patients for partial surgery with conservation of voice and airway

Therefore it was considered of interest to elucidate whether the application of angiography could improve the radiologic evaluation of laryngeal carcinoma For this purpose angiography of normal and some pathologic specimens was performed and the results are now reported

The larynx is supplied by the superior and inferior laryngeal arteries which are branches of the superior and inferior thyroid arteries respectively (RAUBER KOPSCH 1955) The superior laryngeal artery usually enters the larynx through the thyrohyoid membrane but may enter through the thyroid foramen in the posterior upper part of the thyroid cartilage This was found to be the case in about 20 per cent

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of the patients comprising two Japanese series (ADACHI 1928 OKI 1958) and in 4 per cent of a French material (TERRACOL & GUERRIER 1951) The cricothyroid artery is another branch of the superior thyroid artery that runs anteriorly and caudally along the outside of the thyroid cartilage to the cricothyroid membrane where it joins vessels from the opposite side It penetrates the cricothyroid membrane to anastomose with vessels within the larynx The inferior laryngeal artery accompanies the recurrent laryngeal nerve, to enter the lower posterior part of the larynx

The internal vascular anatomy was demonstrated by a dissection technique supplemented by angiography by BROECKAERT (1904) and by TERRACOL & GUERRIER by angiography of specimens by OKI and SPEIDEN et coll (1977) PEARSON (1975) used microdissection of 20 cleared cadaveric specimens in which the vessels had been injected with a coloured colloidal suspension (Chromopaque)

The superior laryngeal artery ramifies between the thyroid cartilage and the intrinsic laryngeal muscles (TERRACOL & GUERRIER) After giving off an ascending branch to the epiglottis and the valleculae the artery usually splits in 2 descending branches one anterior and one posterior which could be connected by a third branch l arcade transverselle superficielle at the lower level of the thyroid cartilage these three arteries form a triangle TERRACOL & GUERRIER assigned subjects into 4 groups according to whether all sides of the triangle were present or whether any of them was missing The anterior descending branch anastomosed with the cricothyroid artery through or lateral to the cricothyroid membrane Anastomoses between the two hemilarynges also exist via the dorsal branches in the postericoid region via the epiglottic branches and via the cricothyroid arteries in front of the cricothyroid membrane

The anatomic findings of PEARSON are consistent with the radiographic findings recorded by OKI whose nomenclature is largely adopted in the present report In 3 of the 20 specimens PEARSON found that the superior laryngeal artery entered the larynx through a thyroid foramen Inside the larynx it gave rise to 5 main branches An ascending branch passing across the upper end of the piriform sinus towards the midpoint of the lateral edge of the epiglottis a ventral branch running along the ventricle to an upturned termination in front of the saccule a medial branch penetrating into the false vocal cord a dorsal branch crossing the floor of the piriform sinus to reach the postericoid region and a descending branch continuing inferiorly outside the thyroarytenoid muscle to divide into an anterior and a posterior division The anterior division left the larynx through the cricothyroid triangle—

Fig 1 Normal specimen Contrast medium and Microfil injected into the left superior laryngeal artery Lateral aspect a) Cleared specimen b) Angiography c) Drawing AB – ascending branch AR – anterior ramus CTA – anterior cricothyroid arcade DB – dorsal branch I – inferior laryngeal artery LD – lateral division PESB – proximal branch to the pre epiglottic space PR – posterior ramus S – superior laryngeal artery TB – terminal bifurcation VB – ventral branch catheter (→) cricothyroid artery (↔)

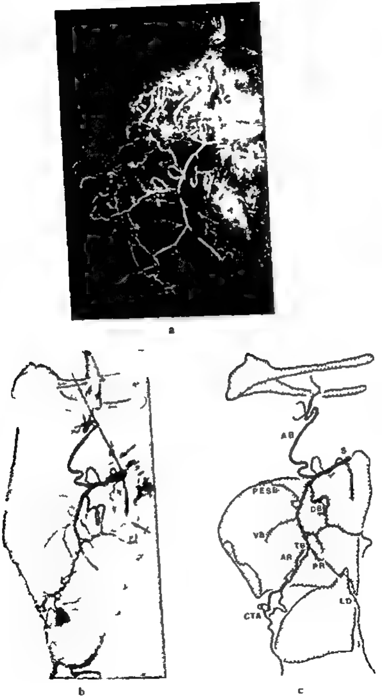


Fig 1 (For legend see opposite page)

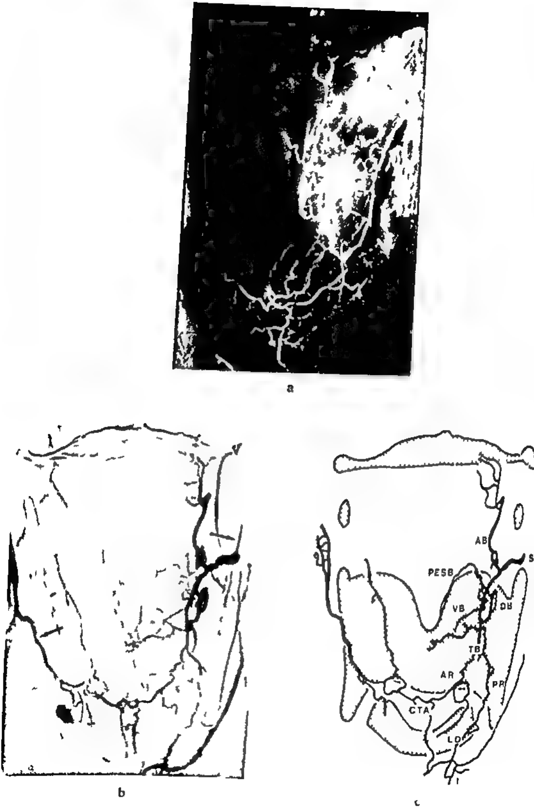


Fig 2 (For legend see opposite page)

bounded by the cricothyroid membrane the thyroid cartilage and the medial edge of the cricothyroid muscle—to anstomose with the cricothyroid artery and the contralateral anterior division via vessels crossing the midline outside the cricothyroid membrane The posterior division descended across the lateral surface of the lateral cricoarytenoid muscle to anastomose with the lateral division of the inferior laryngeal artery ascending near the lateral margin of the posterior cricoarytenoid muscle A medial division of the inferior laryngeal artery ascended along the posterior surface of the posterior cricoarytenoid muscle to reach the dorsal branch of the superior laryngeal artery behind the cricoarytenoid joint

The microvascularity of the larynx in carcinoma and in normal specimens has been investigated by FREELAND (1975) OLSZEWSKI (1976) and GUERRIER & ANDREA (1977) In common with PEARSON they found a similarity between the course of the arteries and the usual routes of tumour spread The ossified parts of the cartilage were penetrated by vessels from the perichondrium which might explain why the earliest tumour invasion occurs here (OLOFSSON & VAN NOSTRAND 1973)

Material and Methods

The material comprised normal and pathologic specimens

The normal material consisted of 21 autopsy specimens from adults without upper airway malignancy 14 from males and 7 from females ranging in age from 22 to 88 years mean 70 The larynx was carefully removed including the hyoid bone but not the carotid arteries or the thyroid gland thus often not the cricothyroid arteries

The pathologic material comprised 4 laryngectomy specimens from men 66 to 74 years of age Three of the patients had been operated upon following irradiation Case 1 had a supraglottic tumour with extension to the base of the tongue Cases 2 and 3 had glottic carcinomas the former with sub- and supraglottic extension and the latter with subglottic extension Case 4 had primary surgery for a glottic carcinoma with marked subglottic and slight supraglottic extension

Angiography In 13 of the 21 autopsy specimens the contrast medium was injected into one superior laryngeal artery and in 7 into one inferior laryngeal artery In one specimen the injection was made into the superior laryngeal artery on one side and the inferior artery on the other

In the pathologic specimens the vessels were marked with ligatures at the operation and the angiography was performed immediately after the larynx had been removed

The relevant laryngeal artery was cannulated with a Portex intravenous cannula (OD 0 63 or 0 75 mm) and perfused with isotonic saline The specimens were

Fig 2 Same specimen as in Fig 1 Anterior aspect a) Cleared specimen b) Angiography c) Drawing. (Abbreviations as in Fig 1)

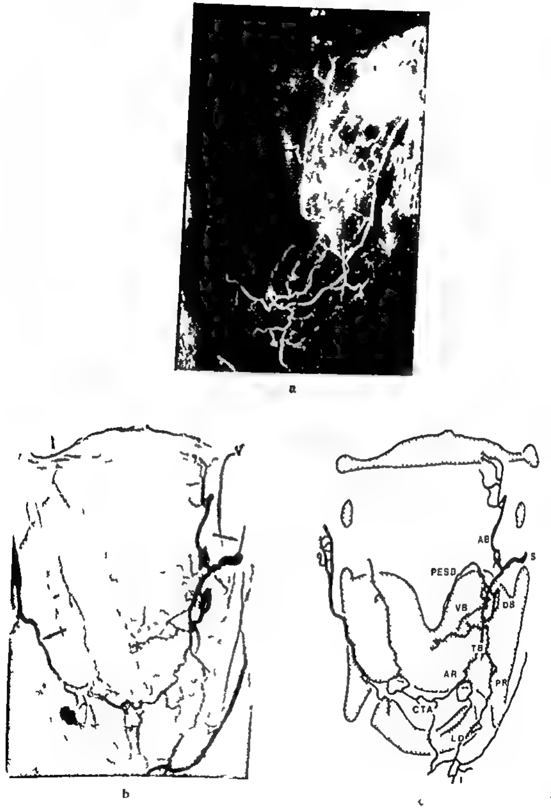


Fig 2 (For legend see opposite page)

a b c d

Fig 3 Normal specimens Contrast medium and Microfil injected into the superior laryngeal artery a) Cleared specimen lateral aspect and c) angiography lateral view of a specimen with the terminal bifurcation at a high level (→) b) Cleared specimen lateral aspect and d) angiography lateral view of a specimen with the terminal bifurcation at a low level (→)

mounted on a frame and stretched by suitably placed sutures After injection of, in turn 0 25 0 50 0 75, 1 5 ml of contrast medium alternate a p and lateral films were exposed without moving the specimen Preliminary films were exposed for subtraction The contrast medium was Bilivistan (ioglycamic acid) and FFD 80 cm Kodak Min R screens and Kodak Structurix C films were used The exposure data were 40 kV and 80 to 100 mAs

Preparation technique Normal specimens Angiography was followed by injection of yellow Microfil (Canton Bio Medical Products Boulder, Colorado) a silicone rubber compound The specimens were then fixed in buffered formalin decalcified in formic acid and dehydrated in alcohol They were then placed in methyl salicylate to clear them and render the cartilages and most of the soft tissues translucent thereby facilitating observation of arteries beneath the cartilages, when the muscles investing the larynx had been removed Photographs were taken from various angles

The evaluation was based mainly on an analysis of the angiograms The cleared specimens were used to elucidate the angiographic findings and to examine the relationship between the vessels and the laryngeal structures

Pathologic specimens After the angiography was completed the 4 pathologic specimens were processed and whole organ serial sections were cut The angiographic appearances were evaluated by comparison to the microscopic appearances

Results

Normal specimens

Superior laryngeal artery (Figs 1–3) The entry of 35 superior laryngeal arteries into the larynx was demonstrated bilaterally in all 14 specimens in which the contrast medium was injected into the superior laryngeal artery and on the ipsilateral side in the 7 specimens in which the injection was made into the inferior artery One artery passed through the thyroid foramen whereas 34 passed through the posterior lower part of the thyrohyoid membrane

The course and the branches of the superior laryngeal artery were investigated on the side of the injection in 14 specimens Within the larynx the superior laryngeal artery ran medially for 4 to 5 mm, and then assumed a ventro caudal course along the inner surface of the thyroid ala lateral to the intrinsic laryngeal muscles this course either was straight or had a slight medial convexity, with a variable length of up to 3 cm and ended in a terminal bifurcation

The ascending branch originated at the level of the upper border of the thyroid cartilage This branch ran medio cranially along the lateral border of the epiglottis and gave off branches to the pre epiglottic space The first of these branches demonstrated in 10 of the 14 specimens often originating directly from the superior laryngeal artery was directed anteriorly along the upper border of the thyroid cartilage in a cranially convex curve (Fig 6)

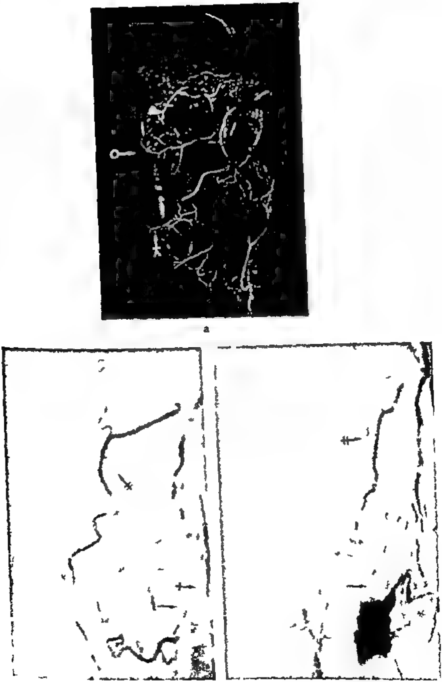


Fig 4 (For legend see opposite page)

The dorsal branch originated 0 to 6 mm below the upper border of the thyroid cartilage, and followed a dorso caudal course medially in 13 of the 14 specimens and slightly laterally in one (Figs 1, 2) In all but one case this branch formed characteristic hair pin bends just distal to its origin, lateral to the lateral cricoarytenoid muscle in the submucosa of the ventral part of the piriform sinus In an attempt to account for the redundant length of this branch, another fresh specimen was dissected after injecting Microfil, the hair pin bends disappeared when the larynx was stretched The dorsal branch contributed to a rich vascular network in the post cricoid region, and anastomosed with the medial division of the inferior laryngeal artery

The ventral branch originated 2 to 12 mm below the upper border of the thyroid cartilage and in all but one of the specimens, distal to the dorsal branch It turned ventro medio caudally and passed lateral to and along the false vocal cord and the laryngeal ventricle Anteriorly this vessel passed beneath the mucosa of the laryngeal ventricle and at a site corresponding to the sacculus it turned upwards This curve was demonstrated in 7 of the 14 specimens In some of the specimens anastomoses existed between the ventral branch and cranio caudally directed vessels in the vicinity of the anterior commissure

One or usually more branches ran to the false vocal cord corresponding to the medial branch described by PEARSON but their course was not constant

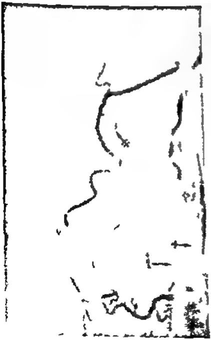
The superior laryngeal artery ended in a terminal bifurcation to form an anterior and a posterior ramus (the anterior and posterior divisions of the descending branch in Pearson s nomenclature) The level of the terminal bifurcation varied considerably ranging from 5 mm above the horizontal surface of the vocal cord to 7 mm below (Fig 3)

The anterior ramus followed a straight or meandering course in a ventro medial and usually caudal direction depending on the level of the terminal bifurcation This ramus ran lateral to the cricothyroid membrane, leaving the larynx to join transverse vessels—the anterior cricothyroid arcade—just outside the cricothyroid membrane thereby anastomosing with the contralateral anterior ramus and both cricothyroid arteries The anterior cricothyroid arcade followed a winding course in 8 specimens and a straight course in 2 and was not observed in 4 In 4 of the 14 specimens mid sagittal and para sagittal vessels followed a straight cranio caudal course on each side of the cricothyroid membrane

The posterior ramus followed a dorso caudal somewhat lateral straight course towards the posterior lower border of the thyroid cartilage to anstomose with the lateral division of the inferior laryngeal artery

Fig 4 Normal specimen Contrast medium and Microfil injected into the left inferior laryngeal artery a) Cleared specimen anteriorly from the left Air bubble captured in anterior part of the larynx Anterior commissure (o→) Anterior cricothyroid arcade (→) b) Angiography lateral view c) Angiography a p view The lateral division (→) of the inferior laryngeal artery anastomoses with the posterior terminal ramus of the superior laryngeal artery The medial division (↔) of the inferior laryngeal artery anastomoses with the dorsal branch (⇻) of the superior laryngeal artery

a



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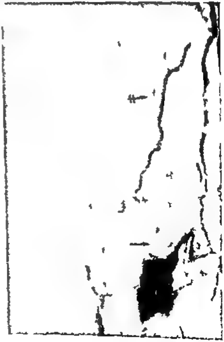

c

Fig 4 (For legend see opposite page.)

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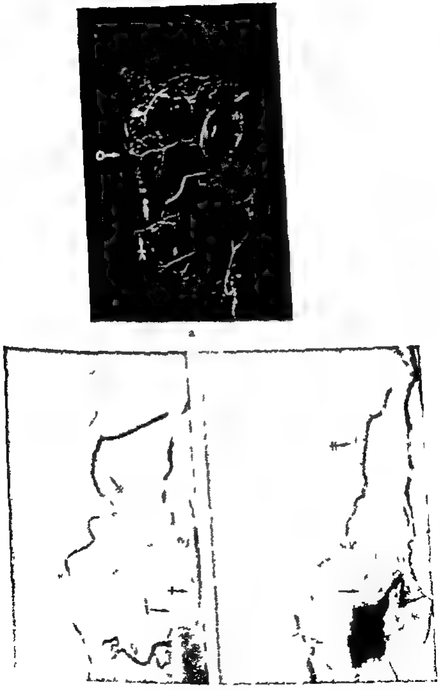

Fig 4 (For legend s e opposite page)

ig 5 (For legend see opposite page)

In one of the 14 specimens no true terminal bifurcation was found Instead the anterior ramus was a direct continuation of the superior laryngeal artery and from the dorsal branch a slender posterior ramus was given off

On the films of 2 patients and in the cleared specimens of another 3 an anastomosing antero posterior branch—the transverse arcade—(l arcade transverselle superficielle TERRACOL & GUERRIER) was found at the level of the lower border of the thyroid ala uniting the anterior and posterior rami

Inferior laryngeal artery (Fig 4) In most of the specimens the catheter was inserted into one of the branches of the inferior thyroid artery rather than in the inferior laryn eal artery Because of a leakage of medium no detailed angiographic examination of the main stem and its branches could be made However the dorsal branch and segments of the main trunk of the ipsilateral superior laryngeal artery were filled consistently and sometimes also the contralateral one In most cases there appeared to be anastomoses also to the posterior ramus

In the cleared specimens a number of slender vessels leading to the post-cricoid region and originating from the inferior laryngeal artery was observed In 7 specimens one somewhat larger vessel existed the medial division that ran cranially to anastomose with the dorsal branch of the superior laryngeal artery In 3 specimens another vessel the lateral division anastomosed with the posterior ramus of the superior laryngeal artery

Laryngeal carcinoma specimens

In case 1 (Fig 6) vessels in the pre-epiglottic space were occluded and invasion was confirmed at microscopy In case 2 the angiographic appearance was normal Microscopy demonstrated a superficial glottic and subglottic tumour which neither invaded the cartilage nor spread outside the larynx In case 3 the ventral branch was occluded at the level of the mid part of the vocal cord Microscopic examination disclosed deep tumour invasion of this area and of the anterior part of the thyroid ala On the films the arteries along the cricothyroid membrane were displaced corresponding to confirmed extra laryngeal spread of the tumour through this membrane In case 4 (Fig 5) the arteries close to the terminal bifurcation on the same side as the tumour were narrow This was ascribed to tumour tissue which however could not be confirmed at microscopy The ventral displacement of the vessels outside the cricothyroid membrane was suggestive of tumour invasion and this was confirmed at microscopy

Fig. 5 Glottic-subglottic carcinoma on the left side Primary surgery (Case 4) a) Coronal section through the midpart of the vocal cords Haematoxylin Eosin stain b) Coronal section through the cricothyroid membrane Tumour (→) Weigert s elastic stain c) Angiography Left superior laryngeal artery lateral view Narrowing of the arteries close to the terminal bifurcation (→) d) Angiography Right superior laryngeal artery lateral view The anterior cricothyroid arcade is displaced anteriorly (↔) C = cricoid cartilage E = epiglottis H = hyoid bone S = spread of tumour through the cricothyroid membrane T = thyroid cartilage THY = thyroid gland

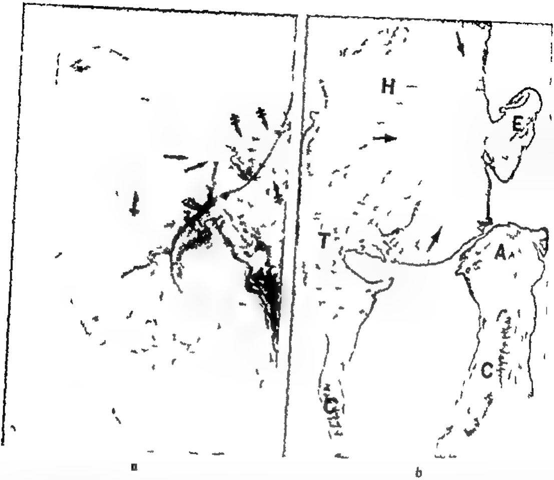

Fig 6 Tumour of the epiglottis with invasion of the pre epiglottic space Combined therapy (Case 1) a) *Angiography* Left superior laryngeal artery lateral view Occlusion of vessels to the *pre epiglottic space* (→) Normal appearance of the proximal branch to the pre-epiglottic space (↔) The rich vascular *network* (⇸) on the laryngeal surface of the epiglottis corresponded to pseudo-epitheliomatous hyperplasia (after irradiation) b) Sagittal section to the left of the midline Tumour (→) *invading the pre epiglottic* space and the base of the tongue A = arytenoid cartilage C = cricoid cartilage E = *epiglottis* H = *hyoid* bone T = thyroid cartilage

Discussion

The analysis of the *films against* the background of the observations made on the cleared specimens indicate that the arterial anatomy of the larynx is fairly constant and characteristic The laryngectomy specimens of the patients with laryngeal carcinoma displayed vascular abnormalities that corresponded to microscopic evidence of deep invasion and spread outside the larynx through the cricothyroid membrane, and invasion of the pre epiglottic space *These observations* suggest that *angiography might* be a *clinically* useful method for ascertaining the extent of tumour spread

Normal anatomy The general arterial anatomy of the larynx as demonstrated in the specimens is consistent with the findings reported by TERRACOL & GUERRIER

SPEIDEN et coll and PEARSON This applies to the entry of the superior laryngeal artery into the larynx the various branches and anastomoses

The internal laryngeal arteries ramify medial to the thyroid cartilage and lateral to the intrinsic laryngeal muscles The comparison by TERRACOL & GUERRIER of the internal laryngeal vessels to a triangle is a simplified description which does not take into account the ventral or the dorsal branches In most of the present specimens only the anterior and posterior sides of this triangle were present corresponding to the anterior and posterior rami respectively whereas the base of the triangle—the transverse arcade—was usually so small as to escape detection if not absent altogether The position of the vertex of the triangle corresponding to the terminal bifurcation varied widely which sometimes made it difficult to distinguish the anterior ramus from the transverse arcade (Fig 3)

Because of the location of the major branches just medial to the thyroid cartilage the tumour has at least to be approaching the cartilage before it causes vascular occlusion

A notable anatomic feature was the appearance of the arteries along the cricothyroid membrane a common pathway for tumour spread outside the larynx (OLOFSSON & VAN NOSTRAND)

Invasion of the pre-epiglottic space may be difficult to detect by conventional methods One possible indicator is occlusion of ramifications of the ascending branch to the pre-epiglottic space In addition the branch extending along the upper border of the thyroid cartilage might well serve as an antero-lateral landmark

The dorsal ramus which is easily identified by the hair pin bends submucosally in the piriform sinus may aid in determining tumour spread to this region

Pathologic specimens The vascular abnormalities most likely to be encountered in carcinoma are changes in calibre occlusion displacement and neo-vascularity Changes in calibre due to tumour encasement might be impossible to differ from those caused by inflammation or atheromatosis this last being the most likely cause in case 4 (Fig 5) Vascular occlusion probably caused by the tumour rather than by artefacts occurred in case 1 with invasion of the pre-epiglottic space (Fig 6) and in case 3 with invasion of the thyroid cartilage Vascular displacement along the cricothyroid membrane present in cases 3 and 4 corresponded to confirmed tumour spread through this membrane The fact that none of the laryngectomy specimens displayed tumour neo-vascularity could have its explanation in the injection technique or in 3 of the cases in the preoperative radiation therapy

Conclusions

(1) The arterial anatomy of the larynx is fairly constant and characteristic

(2) The arterial branches are located just medial to the thyroid cartilage and just outside the cricothyroid membrane—areas of particular interest in the assessment of tumour spread

(3) Arterial abnormalities, probably produced by the tumour, were found in laryngectomy specimens

(4) In view of the promising present results further examination of the diagnostic value of angiography in laryngeal carcinoma should be pursued in the clinical practice

Acknowledgements

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SUMMARY

For a correct selection of patients with laryngeal carcinoma for surgery especially when partial surgery is contemplated it is important to ascertain the extent of deep tumour invasion The usual radiologic methods and microlaryngoscopy have shortcomings in this respect Angiography of normal specimens demonstrated that the arterial anatomy is fairly constant and characteristic Specimens from carcinoma patients displayed vascular abnormalities related to deep invasion as demonstrated at microscopic examination

ZUSAMMENFASSUNG

Zu einer genauen Selektion von Patienten mit einem Larynx Karzinom fur die chirurgische Behandlung besonders wenn eine partielle Operation vorgesehen ist ist es wesentlich die Tiefenausdehnung des Tumors festzustellen Die gewohnlichen rontgenologischen und mikrolaryngoskopischen Methoden sind unzureichend in dieser Hinsicht Die Angiographie von normalen Praparaten zeigte dass die arterielle Anatomie ziemlich konstant und charakteristisch ist Praparate von Karzinompatienten zeigten vaskulare Abnormalitäten die zur Tiefenausdehnung relatiert waren wie mikroskopische Untersuchungen nachgewiesen haben

RÉSUMÉ

Pour choisir correctement les malades atteints de carcinome du larynx qui doivent etre traités par la chirurgie particulièrement quand on se propose de faire une chirurgie partielle il est important de déterminer l extension de l invasion tumorale en profondeur Les méthodes radiologiques habituelles et la microlaryngoscopie ont des insuffisances à cet égard L angiographie de pièces normales a montré que l anatomie artérielle est assez constante et caractéristique Des pièces prélevées sur des malades atteints de carcinome ont montré des anomalies vasculaires en rapport avec l invasion en profondeur telle qu elle est mise en évidence par l examen microscopique

REFERENCES

ADACHI B Anatomie der Japaner Vol I Das Arteriensystem der Japaner Band I S 66 Verlag der Kaiserlich Japanischen Universitat Kyoto 1928

BROECKAERT Recherches sur les artères du larynx Rev hebd Laryng Otol Rhino 24 (1904) 369

FRIEDLAND A P Microfil angiography A demonstration of the microvasculature of the larynx with reference to tumor spread Canad J Otolaryng 4 (1975) 111

GUERRIER Y et ANDREA M La vascularisation des cartilages du larynx Son importance clinique Ann Otolaryng (Paris) 94 (1977) 273

OKI T The distribution of blood vessels in the larynx (In Japanese with extensive English summary) J Otorhinolaryng Soc Japan 61 (1958) 1827

OLOFSSON J and VAN NOSTRAND A W P Growth and spread of laryngeal and hypopharyngeal carcinoma with reflections on the effect of preoperative irradiation 139 cases studied by whole organ serial sectioning Acta oto laryng (1973) Suppl No 308

— and SÖKJER H Radiology and laryngoscopy for the diagnosis of laryngeal carcinoma Acta radiol Diagnosis 18 (1977) 449

— — Radiologic assessment of laryngeal carcinoma A clinico-pathologic comparison based on whole-organ serial sections Acta radiol Diagnosis 20 (1979)

OLSZEWSKI E Vascularization of ossified cartilage and the spread of cancer in the larynx Arch Otolaryngol 102 (1976) 200

PEARSON B W Laryngeal microcirculation and pathways of cancer spread Laryngoscope 85 (1975) 700

RAUBER A A und KOPSCH F Lehrbuch und Atlas der Anatomie des Menschen 19 Aufl Durchgesehen und verbessert von F Kopsch Band 1 S 546 564 Georg Thieme Verlag Stuttgart 1955

SPEIDEN L M TUCKER JR G and SOULEN R Angiography of the larynx An anatomic study in cadaver larynges Canad J Otolaryng 1 (1972) 219

TERRACOL J et GUERRIER Y Le système artériel du larynx Étude anatomique Montpellier Med 39 40 (1951) 341

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CALCIFIED PERIARTHRITIS AT MULTIPLE SITES INCLUDING LUMBAR INTERVERTEBRAL DISCS

Report of a case

J. FRIIS, E. M. JENSEN and A. K. KARLE

Calcific deposits in intervertebral discs form part of a rather distinct syndrome in childhood (EYRING et coll. 1964). The prevalence in adults is about 6 per cent (BYWATERS et coll. 1971) but solid calcification of several discs is uncommon, especially at younger ages.

Extensive calcifications may be secondary to ochronosis, hemachromatosis, chondrocalcinosis, hyperparathyroidism, poliomyelitis and acromegaly (WEINBERGER & MEYERS 1978). SANDSTRÖM (1951) pointed out that intervertebral disc calcifications in adults may also constitute a distinct disease entity. The structure of annulus fibrosis is similar to ordinary tendinous tissue elsewhere in the body while nucleus pulposus consists of thin, sparse connective tissue resembling the peritendinous tissue. Because of these similarities SANDSTRÖM postulated a close relationship between calcific deposits in the intervertebral discs and in tendons and at periarticular sites, most often in the soft tissue between the acromion and the head of the humerus. This hypothesis appears to be supported by a case observed at this hospital.

Case report

The patient is a Caucasian woman aged 32 years. Her mother has disc degeneration and spondylosis, a daughter has osteochondritis of the left knee, otherwise no disposition to joint disease was found. The patient has had psoriasis since the age of 12 years. When she

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Fig 1 Calcification at the greater tubercle on both sides

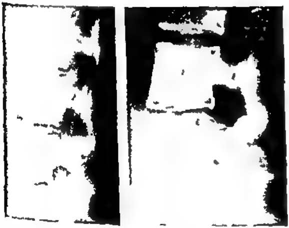

Fig 2 Calcifications in the 4 lower lumbar discs

was 73 years old she had a painful left shoulder and at radiography soft tissue calcification in both shoulder regions The symptoms subsided gradually but have recently reappeared first in the left shoulder then in the right shoulder at times combined with low back pain and some arthralgia of the distal interphalangeal joints

On examination the clinical signs were sparse psoriasis of skin and nails No pigmentation of the skin and no enlargement of the liver Full range of motion in the shoulder joints the hip joints and the lumbar spine Normal Schober s test and chest expansion Tenderness of the lumbar intervertebral discs and the distal interphalangeal joints but no joint swelling

Calcifications were found in the shoulder region (Fig 1) proximal to the left greater trochanter (Fig 3) and in the 4 lower intervertebral discs of the lumbar spine (Fig 2) No calcific deposits at other sites and the sacroiliac joints were normal

All standard laboratory tests were normal including ESR rheumatoid factor antinuclear factor serum calcium serum phosphorus iron iron binding capacity liver function creatinine and uric acid No glucosuria or urinary excretion of homogentisic acid Parathyroid hormone was slightly elevated at one occasion normal at re-examination The major histocompatibility antigens were HLA A2 3 B17 27 Cw1 (tissue typing performed at the Tissue Typing Laboratory Rigshospitalet Copenhagen)

Fig. 3. Calcification in the trochanteric area.

Discussion

Psoriasis may be the explanation of the arthralgia of the distal interphalangeal joints. No signs of spondylitis were found at clinical examination and the calcifications observed cannot be attributed to psoriasis or to any of the disorders in which calcific deposits in the intervertebral discs are common. The evaluation may be that this is a case of calcified tendinitis including the lower lumbar intervertebral discs, a disease sui generis as pointed out by SANDSTRÖM. It is characteristic that, except for mild inconstant pain on motion in the affected joints, the patients feel well between attacks. In the original series of SANDSTRÖM (1938) were 2 or more joints involved in 142 of 329 patients with calcific deposits, usually 2 shoulders or a hip and a shoulder. Only 5 patients had 3 or more joints affected.

WELFLING et coll. (1966) similarly noted calcifications adjacent to the greater trochanter in 15 of 23 patients with calcifications in one or both shoulders. In the same year, PINALS & SHORT published 4 cases with calcific periarthritis at multiple sites around peripheral joints. Hydroxyapatite is the dominating mineral in all extra-articular calcific deposits (GATTER & MCCARTY 1967). Acute exacerbations in relatively quiescent osteoarthrosis may have a similar etiology (DIEPPE et coll. 1976).

It seems reasonable that the syndrome might have a genetic background. The condition is described in monocytic twins (CANNON & SCHMID 1973). It is not clear which importance should be attached to the tissue type of the patients. The histocompatibility antigen HLA B27 is associated mainly with seronegative spondylarthritis but also with the disease of Forestier or diffuse idiopathic skeletal hyperostosis

characterised by diffuse calcifications and ossification along the lateral aspects of the vertebral bodies and extraspinal radiographic abnormalities hyperostosis and exostosis at the sites of ligament attachments on the pelvic bones and calcific deposits in ligaments It has recently been proposed on this account (SHAPIRO et coll 1976) that the HLA B27 gene might be closely related to a gene which influences bone formation The present case does not support the often presented theory that calcific tendinitis should follow degenerative alterations in the tendons (MACNAB 1973)

Addendum in proof

The postulated association between the disease of Forestier and the histocompatibility antigen HLA B27 has lately been questioned (SPAGNOLA et coll 1978)

SUMMARY

A case with calcified periarthritis at peripheral sites and calcification in intervertebral discs gives support to the perception of a distinct disease entity as proposed by SANDSTRÖM The possible significance of genetic factors is discussed

ZUSAMMENFASSUNG

Ein Fall mit einer kalzifizierten Periarthritis in verschiedenen peripheren Gebieten und eine Verkalkung der intervertebralen Wirbelscheiben stutzt die Vorstellung einer bestimmten Erkrankung wie sie von SANDSTRÖM angenommen wird Die mogliche Signifikanz von genetischen Faktoren wird diskutiert

RÉSUMÉ

Un cas présentant une périarthrite calcifiée sur des articulations périphériques et une calcification dans des disques intervertébraux vient étayer l hypothèse d une maladie distincte telle qu elle est proposée par SANDSTROM Les auteurs examinent l importance possible de facteurs génétiques

REFERENCES

BYWATERS E G L HAMILTON E B D and WILLIAMS R The spine in idiopathic haemochromatosis Ann rheum Dis 30 (1971) 453

CANNON R B and SCHMID F R Calcific periarthritis involving multiple sites in identical twins Arthr and Rheum 16 (1973) 393

DIEPPE P A CROCKER P HUSKISSON E C and WILLOUGHBY D A Apatite deposition disease a new arthropathy Lancet I (1976) 266

EYRING E J PETERSON C A and BJORNSON D R Intervertebral disc calcification in childhood J Bone Jt Surg 46A (1964) 1432

GATTER R A and MCCARTY D J Patological tissue calcifications in man Arch Path 84 (1967) 346

McCARTY D J and GATTER R A Recurrent acute inflammation associated with focal apatite crystal deposition Arthr and Rheum 9 (1966) 804
MACNAB I Rotator cuff tendinitis Ann roy Coll Surg Engl 53 (1973) 271
PINALS R S and SHORT C L Calcific periarthritis involving multiple sites Arthr and Rheum 9 (1966) 566
SANDSTRÖM C Peritendinitis calcarea a common disease of middle life Its diagnosis pathology and treatment Amer J Roentgenol 40 (1938) 1
— Calcifications of the intervertebral discs and the relationship between various types of calcifications in the soft tissues of the body Acta radiol 36 (1951) 217
SHAPIRO R F WIESNER K B BRYAN B L UTSINGER P D RESNICK D and CASTLES J J HLA B27 and modified bone formation Lancet I (1976) 230
SPAGNOLA A M BENNETT P H and TERASAKI P I Vertebral ankylosing hyperostosis (Forestier s disease) and HLA antigens in Pima Indians Arthr and Rheum 21 (1978) 467
WEINBERGER A and MEYERS A R Intervertebral disc calcification in adults a review Sem Arthr Rheum 8 (1978) 69
WELFLING J KAHN M F DESROY M et DESÈZE S La maladie des calcifications tendineuses multiple Sem Hôp Paris 42 (1966) 2517

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RADIOGRAPHIC APPEARANCES IN CROHN S DISEASE

II The course as reflected at repeat radiography

J HILDELL, C LINDSTRÖM and A WENCKERT

It is well known that in many patients the extent of Crohn s disease is under estimated at radiography (ATWELL et coll 1965 WILLIAMS 1972) and also that minor lesions cannot be recognized by external inspection and palpation at operation (SHINER & DRURY 1962 ATWELL et coll)

The natural history of the disease has attracted some interest in the clinical literature (SCHOFIELD 1965 WILLWERTH et coll 1971) and attempts have also been made to analyse the course of the disease as reflected at repeat radiography (BRAHME & WENCKERT 1970 JOURDE et coll 1972 BRAHME & FORK 1975)

Previously (Part I HILDELL et coll 1979) radiographic criteria of Crohn s disease were assessed by correlating the macroscopic appearances with the radiographic findings It was found that the macroscopic extent of the disease was often indicated by superficial mucosal lesions which could be observed on high quality films Based on the same material an analysis of the course of the disease in nonoperated patients has been made

Material and Methods

The material for the analysis consisted of 381 examinations of the large and 304 of the small intestine performed in 174 patients

The course and extent of the disease was estimated by a correlation of the results of the repeat radiography with those of operation and microscopy Patients with lesions located mainly in the distal ileum had a mean preoperative radiologic ob-

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Table 1

Extent of disease at the time of operation

Group	Small bowel	Distal ileum	Cecum	Right hemi colon	Left hemi colon	Rectum
A	← 5	→				
B		← 54 →				
C		← 16	→			
D		←	5 →			
E		←	13	→		
F	←	– – – 1		→		
G	←		1			→
H		←		37	→	
I		←		24		→
K			←	1 →		
L			←	2	→	
M			←		14	→
N				←	1	→
	7	156		94		40

servation time of 1 1 years (range 0 1 to 7 years) and patients with involvement of the colon a mean of 2 5 years (range 0 5 to 16 years)

Results

Extent of the disease The localization of the lesions at the time of operation appear in Table 1 and the different sites are indicated with capital letters from A to N

The small intestine was extensively involved in 7 patients (A F G) 2 of these having lesions also in the colon

The distal ileum was involved in 156 patients (A–I) The lesions were part of an extensive disease of the small intestine in 7 patients (A F G) in 54 they were located exclusively in the distal ileum (B) In 21 patients lesions occurred both in the distal ileum and in the cecum (B C) and in 74 also in the colon (E H I)

The cecum was the segment mainly involved in 5 patients (D) with only minor lesions in the distal ileum

The colon was involved in 94 patients (E–N) either as an ileocolic or a pure colic disease

Ileocolic disease was found in 76 patients (E–I) Two main groups could be distinguished (a) Involvement of the right hemicolon (14 patients E F) The disease extended aborally to the middle or right third of the transverse colon (Fig 1) and (b) involvement of the entire colon (62 patients G–I)

Fig 1 Involvement of the right hemicolon only Radiologic follow up of 12 years no lesions in other parts of the colon

Colic disease occurred in 18 patients (K–N) The entire colon was involved in 16 patients (L M) In one patient isolated involvement of the right (K) and in another of the left (N) hemicolon was recorded

The rectum was involved in 40 patients (G I M N) in 25 patients in addition to ileocolic disease (G I) and in 15 combined with colic disease (M N)

Course of the disease Minor lesions in the small intestine were not demonstrated at radiography (Part I) It was not until after single or multiple strictures had developed that a radiologic diagnosis could be made (Fig 2) Therefore evaluation of the course of the disease was not possible in the 7 patients with small intestine disease

In most patients with involvement of the distal ileum (156 patients) the lesions were evident at the first examination (Part I) but the length of the most severely involved aboral segment was difficult to estimate The pathologic process was locally progressive Regression was not observed in any of the patients The length of the involved segment of the distal ileum varied in the resected specimens No correlation was found between the length of this segment and the duration of the disease

The cecum was involved in 5 patients The lesions appeared as a deformity of the cecal region The differentiation from malignancy was difficult in 2 patients (Fig 3) All patients were operated upon soon after the radiography and the development of the process could therefore not be assessed

The colon was involved in 94 patients The distribution and development of the lesions are illustrated in Table 2 The development indicated by Roman numerals from I to XII was correlated with the extent of the disease at the time of operation It is evident that in many patients a borderline existed between severe and minor lesions at the splenic flexure

In patients with ileocolic disease at the first examination the right hemicolon was

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Extent of disease at the time of operation

Group	Small bowel	Distal ileum	Cecum	Right hemicolon	Left hemicolon	Rectum
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F	←	1		→		
G	←		1			→
H		←	37		→	
I		←		24		→
K			← 1	→		
L			←	2	→	
M			←	14		→
N				←	1	→
	7	156		94		40

servation time of 1.1 years (range 0.1 to 7 years) and patients with involvement of the colon a mean of 2.5 years (range 0.5 to 16 years).

Results

Extent of the disease. The localization of the lesions at the time of operation appear in Table 1 and the different sites are indicated with capital letters from A to N.

The small intestine was extensively involved in 7 patients (A, F, G), 2 of these having lesions also in the colon.

The distal ileum was involved in 156 patients (A–I). The lesions were part of an extensive disease of the small intestine in 7 patients (A, F, G); in 54 they were located exclusively in the distal ileum (B). In 21 patients lesions occurred both in the distal ileum and in the cecum (B, C) and in 74 also in the colon (E, H, I).

The cecum was the segment mainly involved in 5 patients (D) with only minor lesions in the distal ileum.

The colon was involved in 94 patients (E–N), either as an ileocolic or a pure colic disease.

Ileocolic disease was found in 76 patients (E–I). Two main groups could be distinguished: (a) Involvement of the right hemicolon (14 patients, E, F). The disease extended aborally to the middle or right third of the transverse colon (Fig. 1), and (b) involvement of the entire colon (62 patients, G–I).

Table 2

Preoperative distribution and course of colic lesions in patients with ileocolitis and colitis

Group	Course	Extent of disease at time of operation: Ileocolic			Colic		No of cases	Median history (years)	Median radiologic follow up (years)	Median No of radiography
I		14			1*		15	3 0 (0 5–12)	1 0 (0 5–12)	2 0 (1–6)
II			14				14	1 5 (0 5–8)	1 25 (0 5–7)	2 5 (1–6)
III	→		2				2	0 75 (0 5–1)	0 75 (0 5–1)	2 5 (1–6)
IV	⇄		6				6	2 0 (0 5–7)	0 9 (0 5–7)	3 0 (1–5)
V	⇄		1	3			4	3 0 (0 5–10)	2 0 (0 5–8)	3 0 (?–5)
VI	⇄		3	3			6	1 75 (0 5–4)	0 5 (0 5–3)	2 5 (2–6)
VII			10	10	1	9	30	3 0 (0 5–[illegible]0)	2 0 (0 5–12)	3 0 (2–5)
VIII	→		1			2	3	3 0 (2–4)	3 0 (1–4)	3 0 (3–4)
IX	→			3			3	5 0 (1–7)	5 0 (0 5–7)	(? 0 (2–4)
X	→			6	1		7	4 0 (2–[illegible]0)	3 5 (?–16)	5 0 (4–6)
XI						3	3	4 5 (0 5–7)	2 5 (0 5–4)	4 0 (–5)
XII						1	1	[illegible]0	[illegible]	2
		14	37	25	3	15	94			

Severe lesions Minor lesions Involvement of right hemicolon only

Microscopy of the presumed skipped areas consistently revealed inflammatory lesions (Fig 5)

Disappearance and reappearance of mucosal lesions (10 patients IV V) occurred sometimes repeatedly and in a short period of time In 6 of these patients the lesions were superficial during the observation period (superficial fluctuating colitis) but in 4 patients they were deeper (Fig 6)

Two patients (X) initially had a pancolitis but at the time of operation mucosal lesions were found only in the left hemicolon Both patients had a long history and microscopy of the resected segments revealed abnormalities considered to represent healed colitis (HILDELL et coll Part I) in the right hemicolon

The rectum was involved in 40 patients in 27 already at the first radiography

Fig 2

Fig 3

Fig 2 Wide spread involvement of small intestine Multiple structures in oral part of ileum

Fig 3 Severe structure of the cecal pole

always involved and in the majority of the patients it was the most severely affected segment

The involvement of the colon alone appeared as a pancolitis in 13 patients as a predominantly left sided colitis in 4 or as a right sided colitis in one

In 63 of the 94 patients the radiographic appearance of the disease varied only slightly In 29 of these patients the lesions were entirely or predominantly located in the right hemicolon (I II)

In 30 patients the lesions were uniformly distributed in the entire colon (VII) and in 4 patients the left hemicolon was the segment mainly involved (XI XII) In the remaining 31 patients (28 with ileocolic and 3 with colic disease alone) the distribution and severity of the lesions changed in several ways

Progression of lesions in the left hemicolon was observed in 13 patients (VIII–X) In 10 of these the progression in the left hemicolon was accompanied by a regression in the right (VIII X Fig 4)

Fluctuation and discontinuity (6 patients VI) The appearance was that of a segmental colitis with different segments involved during the course of the disease

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I		14			1*		15	3.0 (0.5–12)	1.0 (0.5–12)	2.0 (1–6)
II			14				14	1.5 (0.5–8)	1.25 (0.5–7)	2.5 (1–6)
III	→		2				2	0.75 (0.5–1)	0.75 (0.5–1)	2.5 (2–3)
IV	⇄		6				6	2.0 (0.5–7)	0.9 (0.5–7)	3.0 (1–5)
V	⇄		1	3			4	3.0 (0.5–10)	2.0 (0.4–8)	3.0 (2–5)
VI	⇄		3	3			6	1.75 (0.5–4)	0.5 (0.5–3)	2.5 (2–6)
VII			10	10	1	9	30	3.0 (0.5–20)	2.0 (0.5–12)	3.0 ([illegible]–5)
VIII	→		1			2	3	3.0 (2–4)	3.0 (1–4)	3.0 (3–4)
IX	→			3			3	5.0 (1–7)	5.0 (0.5–7)	[illegible].0 (2–4)
X	→			6	1		7	4.0 (2–20)	3.5 ([illegible]–16)	5.0 (4–6)
XI						3	3	4.5 (0.5–7)	[illegible].5 (0.5–4)	4.0 (2–5)
XII						1	1	20	2	2
		14	37	25	3	15	94			

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The rectum was involved in 40 patients in 27 already at the first radiography

Fig 4 a) Disease in entire colon b) 3 years later Right sided lesions have largely disappeared only few punched out ulcers left in transverse colon (→)

In the remaining 13 patients rectal lesions developed during the observation period Rectal involvement was recorded only in patients with more severe lesions in the left hemicolon

Discussion

The present series is the only real retrospective review of radiographic examinations in patients with Crohn's disease dealing with a consecutive series of operatively managed patients and covering a long period of time The only disadvantage from a radiologic point of view is that the present tendency especially during the past 5 years implies early surgical intervention thus preventing a long term follow up which might have been of interest However the results of the analysis differ in many respects from those previously reported

Due to the limitations of the radiographic techniques used the extent of the disease in the small intestine including the distal ileum could not be adequately assessed Nor was it possible to make an adequate evaluation of the course of the disease From what could be observed in repeat films disease of the distal ileum was locally progressive and there was no linear extension across the ileocecal valve or in an oral direction This is in accordance with the findings of MARSHAK & LINDNER (1970) and NELSON et coll (1973) but contrary to the findings of other authors (SCHO-

a

Fig. 5 a) Predominantly right sided colitis Skipped lesion in sigmoid colon (→) b) 2 years later Oral part of descending colon has become involved small skipped area in transverse colon

b

FIELD TRUELOVE 1971 FAHRLANDER & SHALEV 1974 JULIEN & VIGNAL 1976 TRUELOVE & PENA 1976)

At microscopic examination the most advanced abnormalities were usually located in the aboral 20 to 30 cm of the ileum and the severity of the lesions decreased in the oral direction In the most oral parts the disease in many patients manifested itself only as an inflammatory reaction of the submucosa and scattered aphthoid ulcers These abnormalities were not demonstrated at radiography but were observed at microscopy also in patients with a long history the impression being that they were relatively recent This may imply that they were locally recurring but it is also possible that they represented a true linear extension of the disease Whatever theory is correct disease of the distal ileum seems to be restricted principally to a segment of an individually varying but defined length and linear extension in an oral direction if existent appears to occur slowly

In 54 patients the lesions ceased abruptly at the ileocecal valve while 16 patients had additional lesions in the cecum These two groups could not be separated at radiography as involvement of the distal ileum consistenly caused a deformation of the cecum which could not be distinguished from real involvement of the cecum

The lesions of the cecum may represent a linear extension from the distal ileum However as has been reported by WILLWERTH et coll the clinical features of patients

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a

b

c

Fig 6 a) Involvement of entire colon b) 3 years later Ulcers have disappeared No radiographic indication of inflammatory lesion c) After one more year Progression of lesions Scattered superficial ulcers and small nodular defects in transverse and descending colon

with ileal disease were similar to those of patients with ileocecal disease Most likely the involvement of the distal ileum and the cecum occurs simultaneously and ileal and ileocecal disease should be regarded as variants of the same type of Crohn s disease

The varying and fluctuating nature of Crohn s disease in the colon has been con sidered by several authors (JONES et coll 1969 MARSHAK & LINDNER FROMM et coll 1971 BRAHME & FORK JULIEN & VIGNAL, SIMPKINS 1976) but no attempts at closer analysis have been made and clinicians do not seem to be fully aware of this pheno- menon

In previous reports consideration has probably been taken only of the extent of the disease at the time of operation This may explain some of the differences between the present results and others

It was found that isolated left sided colitis if existent is extremely rare Even if the lesions at the time of operation were more advanced in the left hemicolon lesions always existed also in the right hemicolon In most patients a left sided localization was the result of a progression of the lesions in the left hemicolon and a regression in the right In previous reports left sided colitis constituted about 15 per cent of colic Crohn s disease (RITCHIE & LOCKHART MUMMERY 1973 STEINBERG et coll 1974 GREENSTEIN et coll 1975 ENGELHOLM & PEETERS 1976) This figure probably includes cases of pancolitis examined at a time when the right sided lesions had faded and no longer were demonstrable by the examination techniques used This apparent healing of the right hemicolon may also explain why in many series there is a varying number of patients with ileocolitis without involvement of the ascending colon In the present series the right hemicolon was invariably involved in patients with ileocolitis This conclusion based on the results of consecutive radiographic examinations, was confirmed by microscopy made possible by the operative pro- cedures employed In this respect the results agree with those of ENGELHOLM & PEETERS and NELSON et coll

Temporary regression or even disappearance of mucosal lesions have previously been reported from this hospital and by others (JONES et coll MARSHAK & LINDNER BRAHME & FORK JULIEN & VIGNAL SIMPKINS) This possibility should be borne in mind whenever surgical intervention is contemplated A single apparently normal examination of the colon is no guarantee for a non diseased colon

Isolated involvement of intermediary colonic segments have been described by many authors (SCHOFIELD FAHRLANDER & BAERLOCHER 1971 FROMM et coll ENGELHOLM & PEETERS JULIEN & VIGNAL) Such segmental involvement could not be demonstrated in the present series Segmental colitis was always the result of local fluctuations of the lesions and microscopy consistently revealed inflammatory lesions also in areas that were apparently non involved at the time of operation

The role of the lymphatic system in the pathogenesis of Crohn s disease has been considered by several authors (WARREN & SOMMERS 1954 AMMAN & BOCKUS 1961 KALIMA 1970 MORSON 1972 ARONSON et coll 1975) and it is generally agreed that lymphatic obstruction constitutes an essential part of the spectrum of Crohn s disease Some authors have suggested a correlation between the extent of the dis ease and the anatomic distribution of lymphatics and lymph nodes (KALIMA) The great variations in the anatomy of the lymphatic system (SLANETZ & HERTER 1972)

a

b

c

Fig 6 a) Involvement of entire colon b) 3 years later Ulcers have disappeared No radiographic indication of inflammatory lesion c) After one more year Progression of lesions Scattered superficial ulcers and small nodular defects in transverse and descending colon

with ileal disease were similar to those of patients with ileocecal disease Most likely the involvement of the distal ileum and the cecum occurs simultaneously and ileal and ileocecal disease should be regarded as variants of the same type of Crohn s disease

and the possibility of lymphatic blockage and retrograde flow of lymph (BURN 1968) may explain many of the presumed peculiarities that exist in the course and distribution of the lesions

In the distal ileum the disease was radiographically confined to a segment the length of which seemed to be determined at the first radiography Ileal and ileocecal disease may be the same type of Crohn s disease being representatives of differences in the regional lymphatic drainage Diseases of the cecum, previously discussed by SCHOFIELD may be explained in the same way

In many patients the extent of the colonic lesions was limited by the borderline between the superior and inferior mesenteric area of lymphatic drainage Exclusive or predominantly right or left sided colitis may be explained by absence of or sparse communication between these systems

The observation that the rectum is sometimes spared even in severe disease of the sigmoid colon may be explained by the well known alternative lymphatic drainage of the rectum through several separate systems

The abundance of anastomoses in the lymphatic system of the colon may explain why in most instances of colic Crohn s disease the entire colon is involved It may also explain why no isolated involvement of intermediary segments occurs

It is beyond the scope of this report to discuss whether Crohn s disease has its origin in the wall of the intestine the lymphatic vessels or the mesenteric lymph nodes but the results presented should be of significance in discussions concerning different methods of surgical management

SUMMARY

The course and distribution of the lesions in 174 patients with Crohn s disease were evaluated from preoperative films In the small intestine the course was locally progressive Colonic disease involved either the right hemicolon or the entire colon Fluctuations of mucosal lesions were common and could explain the radiographic finding of segmental and left sided colitis Variations in the anatomy of the lymphatic system could explain the varying distribution of the lesions

ZUSAMMENFASSUNG

Der Verlauf und die Verteilung von Darmveränderungen bei 174 Patienten mit Crohns Erkrankung wurden an präoperativen Filmen untersucht Im Dunndarm war der Verlauf lokal progressiv Bei der Erkrankung des Kolons war entweder das rechte Hemikolon oder das gesamte Kolon befallen Fluktuationen der Mucosaveranderung waren gewohnlich und konnten den rontgenologischen Befund einer segmentalen und linksseitigen Kolitis erklären Änderungen in der Anatomie des lymphatischen Systems konnen die veränderliche Verteilung der Läsionen erklaren

RÉSUMÉ

L évolution et la distribution des lésions chez 174 malades atteints de maladie de Crohn ont été étudiées à partir de films pré opératoires Sur l intestin grêle l évolution est locale

ment progressive L atteinte colique touchait soit la moitie droite du colon soit le colon entier Les fluctuations des lesions muqueuses ont été fréquentes et pourraient expliquer les signes radiographiques de colite segmentaire et gauche Les variations dans l anatomie du système lymphatique pourraient expliquer la distribution variable des lésions

REFERENCES

AMMANN W and BOCKUS H L Pathogenesis of regional enteritis Arch intern Med 107 (1961) 504

ARONSON M D PHILLIPS C A BEEKEN W L and FORSYTH B R Isolation and characterization of a viral agent from intestinal tissue of patients with Crohn s disease and other intestinal disorders Progr med Virol 21 (1975) 165

ATWELL J D DUTHIE H L and GOLIGHER J C The outcome of Crohn s disease Brit J Surg 52 (1965) 966

BRAHME F and FORK T Dynamic aspects of colonic Crohn s disease Radiologe 15 (1975) 463

— and WENCKERT A Spread of lesions in Crohn s disease of the colon Gut 11 (1970) 576

BURN J I Obstructive lymphopathy Ann roy Coll Surg Engl 42 (1968) 93

ENGELHOLM L and PEETERS J P Radiology in granulomatous colitis In The management of Crohn s disease p 47 Edited by I T Weterman A S Pena and C C Booth Excerpta Medica Amsterdam 1976

FAHRLANDER H and BAERLOCHER CH Clinical features and epidemiological data in the Basle area In Regional enteritis (Crohn s disease) Skandia International Symposia p 131 Edited by A Engel and T Larsson Nordiska Bokhandelns Forlag Stockholm 1971

— und SHALEV E Die Enterocolitis regionalis Crohn Eine Verlaufs und Vergleichsstudie anhand von 182 Patienten Dtsch med Wschr 99 (1974) 2207

FROMM H WILSON F RODGERS JR J and BALINT J Granulomatous bowel (Crohn s disease) A retrospective study of the course and treatment Arch intern Med 128 (1971) 739

GREENSTEIN A J GELLER S A DREILING D A and AUFSES A H Crohn s disease of the colon IV Clinical features of Crohn s (ileo) colitis Amer J Gastroent 64 (1975) 191

HILDELL J LINDSTRÖM C and WENCKERT A Radiographic appearance in Crohn s disease I Accuracy of radiographic methods Acta radiol Diagnosis 20 (1979) 609

JONES J H LENNARD JONES J E and YOUNG A C Reversibility of radiological appearance during clinical improvement in colonic Crohn s disease Gut 10 (1969) 738

JOFFROY L BOUSKELA R MONNIER J P Colite granulomateuse Aspects radiologiques en fonction du stade évolutif J Radiol Électrol 53 (1972) 769

JULIEN M et VIGNAL J La maladie de Crohn recto-colique J Chir (Paris) 112 (1976) 51

KALIMA T V Experimental lymphatic obstruction in the ileum Ann Chir Gynaec Fenn 59 (1970) 187

MARSHAK R H and LINDNER A E Granulomatous colitis and ileocolitis with emphasis on the radiological features Progr Gastroent 1 (1970) 357

MORSON B C Pathology of Crohn s disease Clin Gastroent 1 (1972) 262

NELSON J A MARGULIS A R GOLDBERG H I and LAWSON T L Granulomatous colitis Significance of involvement of the terminal ileum Gastroenterology 64 (1973) 1071

RITCHIE J K and LOCKHART MUMMERY H E Non restorative surgery in the treatment of Crohn s disease of the large bowel Gut 14 (1973) 263

SCHOFIELD P F The natural history and treatment of Crohn s disease Ann roy Coll Surg Engl 36 (1965) 258

SHINER M and DRURY R A B Abnormalities of the small intestinal mucosa in Crohn s disease (Regional enteritis) Amer J dig Dis 7 (1962) 744

SIMPKINS K C The barium enema in Crohn s colitis *In* The management of Crohn s disease p 62 Edited by I T Weterman A S Pena and C C Booth Excerpta Medica Amsterdam 1976

SLANETZ C A *and* HERTER F P *The large intestine In The lymphatics in cancer p* 489, Edited by C D Haagensen C R Feind F P Herter C A Slanetz and J A Weinberg W B Saunders Philadelphia 1972

STEINBERG D M, ALLAN R N THOMPSON H BROOKE B N ALEXANDER WILLIAMS J and COOKE W T Excisional surgery with ileostomy for Crohn s colitis with particular reference to factors affecting recurrence Gut 15 (1974) 845

TRUELOVE S C Course and prognosis *In* Regional enteritis (Crohn s disease) Skandia International Symposia p 116 Edited by A Engel and T Larsson Nordiska Bokhandelns Forlag Stockholm 1976

— and PENA S Course and prognosis of Crohn s disease Gut 17 (1976) 192

WARREN S and SOMMERS S C Pathology of regional enteritis and ulcerative colitis J Amer med Ass 154 (1954) 189

WILLIAMS J A Surgery and the management of Crohn s disease Clin Gastroent 1 (1972) 469

WILLWERTH B DECOSSE J J DWORKEN H J MCKILLOP D B and VELLIOS F Natural *history of regional enterocolitis Arch Surg* 103 (1971) 315

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EXCRETION OF SODIUM IOTHALAMATE AT COMPRESSION UROGRAPHY AFTER FUROSEMIDE DEHYDRATION IN THE RABBIT

T. OWMAN

The standard procedure for urography with low doses (20–40 ml of contrast medium containing 300–350 mg I/ml) has up to now usually involved fluid restriction and overnight fasting (KEATES 1953). After the introduction of large dose urography and infusion urography (SCHENKER 1964, DURE-SMITH 1966, HARTLEY 1966, CATTELL et coll. 1967, DOYLE et coll. 1967, SHERWOOD et coll. 1968 a) the opinions have differed as to the need of fluid deprivation. SHERWOOD et coll. (1968 b) considered that short term fluid deprivation was of value even in large dose urography while GLANVILLE & HERLINGER (1966) were of the opposite opinion. In order to establish the possible value of furosemide for dehydration before urography experiments in the rabbit were performed.

Material and Methods

Sixteen Swedish landrace rabbits weighing 2.0 to 3.0 kg were used. No overnight fasting or fluid restriction were instituted in the animals receiving furosemide (Lasix, Hoechst, Germany). The animals were anaesthetized intravenously by pentobarbitone sodium (Mebumalnatrium, ACO, Sweden) with supplementary small doses given throughout the experiment when needed. Each ureter was catheterized with a thin baby feeding tube (3.5 F, 1.5 mm, Argyle, England) by a retroperitoneal approach

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SCHOFIELD P F The natural history and treatment of Crohn s disease Ann roy Coll Surg Engl 36 (1965) 258

SHINER M and DRURY R A B Abnormalities of the small intestinal mucosa in Crohn s disease (Regional enteritis) Amer J dig Dis 7 (1962) 744

SIMPKINS K C The barium enema in Crohn s colitis *In* The management of Crohn s disease p 62 Edited by J T Weterman A S Pena and C C Booth Excerpta Medica Amsterdam 1976

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— and PENA S Course and prognosis of Crohn s disease Gut 17 (1976) 192

WARREN S and SOMMERS S C Pathology of regional enteritis and ulcerative colitis J Amer med Ass 154 (1954) 189

WILLIAMS J A Surgery and the management of Crohn s disease Clin Gastroent 1 (1972) 469

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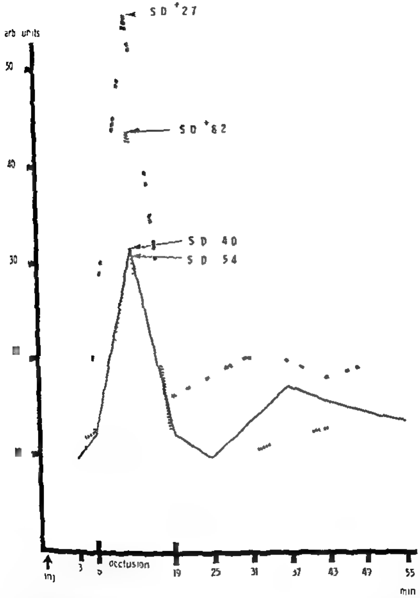

Fig 2. Estimated attenuation of renal pelvis after an intravenous injection of sodium iothalamate 330 mg I/kg b w. During ureteral stasis (occlusion) the highest attenuation was reached after pre treatment with 0 5 mg furosemid. A high attenuation also after pre treatment with 1 0 mg furosemide. No difference between animals pre treated with 0 25 mg furosemide and non-dehydrated animals.
0 25 mg ▬ ▬ 0 5 mg ▪ ▪ ▪ 1 0 mg furosemide —— non-dehydrated

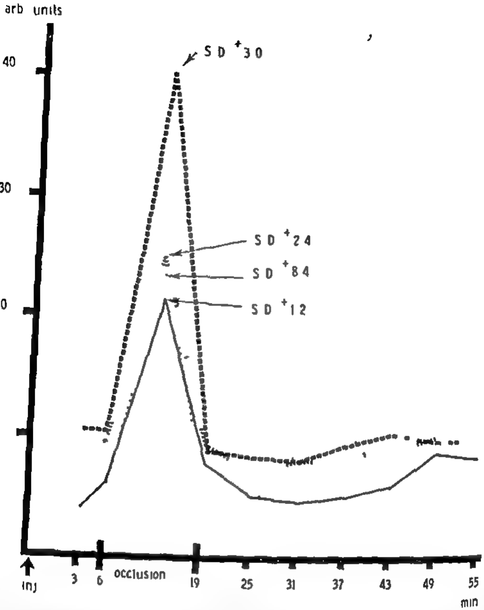

Fig 1 Estimated attenuation of renal pelvis after an intravenous dose of sodium iothalamate 160 mg I/kg b w *During ureteral* stasis (occlusion) the highest attenuation was reached after pre treatment with 0 5 mg furosemide No difference between animals pre treated with 0 25 or 1 0 mg furosemide or non dehydrated animals 0 25 mg ▬ ▬ 0 5 mg ■ ■ ■ 1 mg furosemide —— non dehydrated

and the catheter tip was placed in the renal pelvis The jugular vein and the carotid artery were catheterized for injection of contrast medium arterial blood sampling and blood pressure measurements In 12 rabbits furosemide was given intravenously in doses from 0 25 to 1 0 mg 40 min before the intravenous injection of ¹²⁵I labelled sodium iothalamate (Conray 400) in doses of 160 to 320 mg I/kg body weight Four rabbits subjected to usual over night fasting (referred to as non dehydrated in the text) were used as controls and not given furosemide before the contrast medium

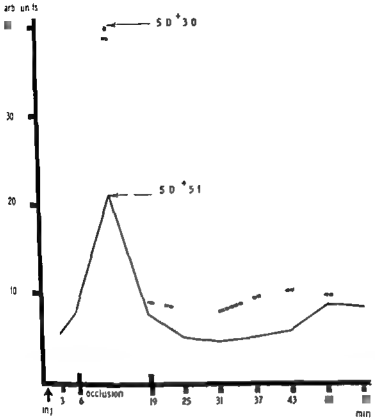

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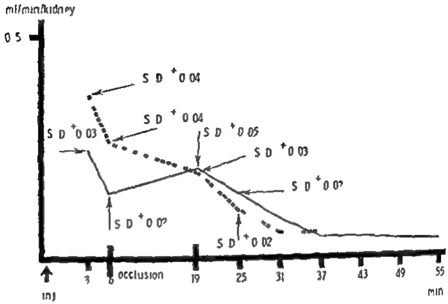
Fig. 3 Diuresis urine iodine concentration and estimated attenuation of the renal pelvis in non dehydrated animals and animals pre treated with 0 5 mg furosemide 160 mg I/kg b w of sodium iothalamate a) Somewhat greater diuresis (larger urinary volume) after pre treatment with furosemide than in non dehydrated animals before catheter clamping b) Somewhat higher iodine concentration during ureteral occlusion was reached after pre treatment with furosemide c) During ureteral occlusion considerably higher relative values for estimated attenuation of renal pelvis were reached in animals pre treated with furosemide than in non-dehydrated animals — — 0 5 mg furosemide —— non-dehydrated

Blood and urine samples were collected according to a schedule reported previously (OWMAN 1979) and corresponding to the time schedule applied in routine compression urography i e after the contrast medium injection the taking of two urine samples each collected over a 3 min period The ureters were then occluded for 12 min followed by one min of drainage and thereafter urine was sampled during 6-min periods The urine specimens were collected in tuberculine or similar syringes and the volumes directly measured The concentration of iodine was determined in each sample using a scintillation detector (Selektronik Denmark)



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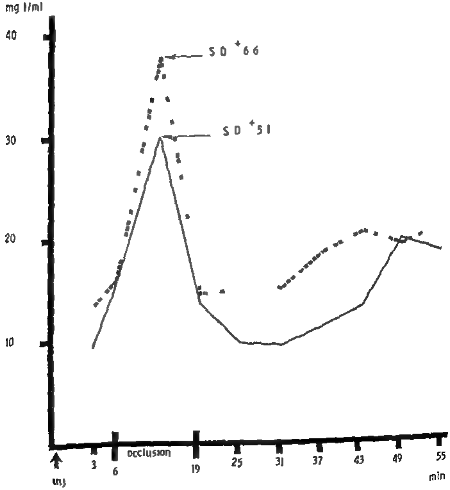

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Fig 3 (For legend see opposite page)

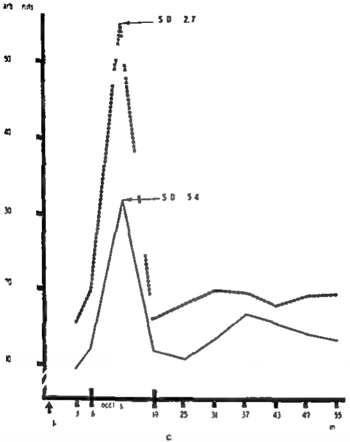
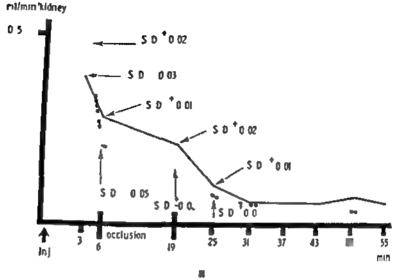
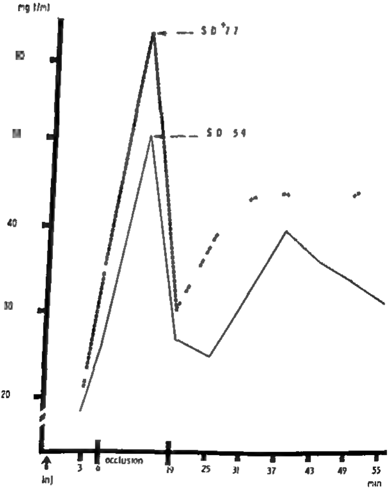


Fig 4 Diuresis urine iodine concentration and estimated attenuation of the renal pelvis in non dehydrated animals and animals pre treated with 0 5 mg furosemide 320 mg I/kg b w of sodium iothalamate a) Greater diuresis (larger urinary volume) after pre treatment with furosemide than in non dehydrated animals before catheter clamping b) Somewhat higher iodine concentration during ureteral occlusion after pre treatment with furosemide c) During catheter clamping considerably higher relative values for estimated attenuation of renal pelvis in animals pre treated with furosemide than in non-dehydrated animals The difference in attenuation was somewhat greater than that for the dose level 160 mg I/kg b w of sodium iothalamate (Fig 3 c) ▬▬ 0 5 mg furosemide —— non-dehydrated

Results

After the intravenous injection of furosemide a rapid increase in diuresis was noted within the first minute The high urinary flow was maintained for 20 to 30 min followed by a slow and gradual fall in diuresis The urinary volume excreted during a 40-min period ranged from 13 5 to 17 5 ml at 0 25 mg furosemide from 26 5 to 47 5 at 0 5 mg furosemide and from 43 7 to 60 5 at 1 0 mg furosemide The urinary flow rate after furosemide depended to some extent also on the basic urinary flow rate After 60 to 80 min the diuresis fell to base line values Haemato-





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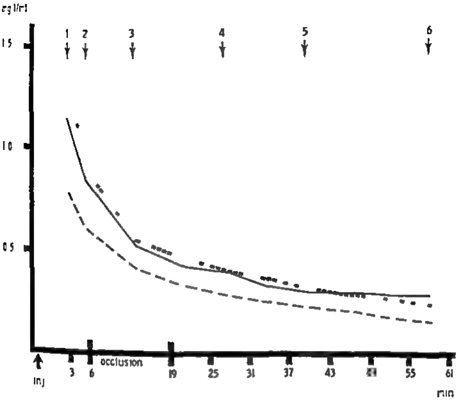

Standard deviations (±*s*)

	1	2	3	4	5	6
0 5 f 160	0 02	0 01	0 03	0 06	0 0_	0 04
0 5 f 3 0	0 01	0 03	0 02	0 01	0 04	0 03
160	0 02	0 05	0 01	0 02	0 03	0 0_
3 0	0 04	0 01	0 04	0 02	[illegible]	0 02

Fig 5 Blood iodine concentration after bolus injection of contrast medium After pre treatment with furosemide higher concentration than in non-dehydrated animals and the blood iodine levels were similar at both dose levels In non-dehydrated animals blood iodine concentration was higher after the injection of 320 mg I/kg b w than after 160 mg I/kg b w of sodium iothalamate In all cases blood iodine concentration declined throughout the observation period and the initial fall in concentration was steeper in pre treated animals ■■ 160 mg I/kg b w and 0 5 mg furosemide —— 3 0 mg I/kg b w and 0 5 mg furosemide 160 mg I/kg b w — — 320 mg I/kg b w

medium (VAN WAES 1972 HARDT 1973) If furosemide is administered before the contrast medium in the present experiments 40 min earlier the osmotic diuresis due to the contrast medium will be mainly unchanged at a dose of 160 mg I/kg body weight and only mildly increased at a dose of 320 mg I/kg body weight The iodine concentration in the urine was in all cases higher after furosemide The estimated

crit values were 3 to 7 per cent higher approximately one hour after the furosemide induced diuresis had begun than before, indicating a decrease in plasma volume

The attenuation capacity of the kidney pelvis is a function of the product of iodine concentration in the urine and the thickness of the layer of contrast containing urine The thickness of the renal pelvis versus the collected urine volume was previously evaluated (OWMAN) and it was thus possible to calculate the estimated attenuation capacity of the pelvis The results of the two different dose levels 160 and 320 mg I/kg body weight, are given in Figs 1 to 4 The renal pelvic attenuation reached a maximum during the period of ureteral stasis (6–12 min after the injection of contrast medium) After release of the ureteral occlusion the attenuation decreased to less than half value and then increased gradually and very slowly throughout the observation period Urinary flow rate had its maximum during the initial 3 min collecting period and diminished gradually after the ureteral occlusion period

The iodine concentration in the blood was in all cases dependent on the dose of contrast medium as demonstrated previously (OWMAN) and always higher after pretreatment with 0 5 mg of furosemide and in non dehydrated animals

The greatest difference in estimated renal pelvic attenuation between dehydrated and non dehydrated animals occurred after furosemide hydration at the 0 5 mg level and the difference was most marked at a dose of 320 mg I/kg body weight

Discussion

Opinions as to the value of pre urographic dehydration vary Some authors find an over night fluid restriction of importance (KEATES BENNESS 1967 SHERWOOD et coll 1968 b McCLENNAN & BECKER 1971) while others regard this as of small or no value (SCHENCKER FRY et coll 1967 DACIE & FRY 1971) GLANVILLE & HERLINGER even found urography superior in the non dehydrated patient SHERWOOD et coll (1968 a) analysing the urine osmolality immediately before urography in patients with impaired renal function found the standard over night fasting regime of no effect in ensuring maximum or even approximately similar states of dehydration in patients with adequate renal function This agrees well with the findings of MILES et coll (1954) that a maximum urinary osmolality is often not even approached by 14 to 18 hours of fluid restriction They also suggested that at least 22 hours dehydration was required for achieving near maximum urinary osmolality In the present experience from experimental urography in the rabbit over night fasting was of little importance

Only a few experiments using diuretics for dehydration are on record CATTELL et coll used bendroflumetazid (5 mg) in a few cases and found the effect similar to that of fluid deprivation for 14 hours

Furosemide has for some years been used to stimulate diuresis in wash out urography and for the diagnosis of intermittent obstruction usually at the pelvi ureteric junction In this technique furosemide is injected about 10 min after the contrast

SUMMARY

Pre treatment with an optimum dose of diuretic administered in appropriate time relation to the injection of contrast medium can improve urographic quality by increasing *urinary iodine concentration as well as diuresis The doses of contrast medium can probably* be reduced

ZUSAMMENFASSUNG

Vorbehandlung mit einer optimalen Dosis eines verabfolgten Diureticums in einer angemessenen Zeit Relation zur Injektion eines Kontrastmittels kann die urographische Qualität durch Anstieg der Urin Jod Konzentration sowie der Diurese verbessern Die Kontrastmitteldosis kann wahrscheinlich vermindert werden

RESUME

Un traitement préparatoire par une dose optimale de diuretique administre en temps convenable par rapport a l injection de moyen de contraste peut ameliorer la qualite de l urographie en augmentant la concentration urinaire en iode en meme temps que la diurèse Les doses de moyen de contraste peuvent probablement etre réduites

REFERENCES

ASPELIN P Effect of ionic and non ionic contrast media on whole blood viscosity plasma viscosity and hematocrit in vitro Acta radiol Diagnosis 19 (1978) 977

BENNESS G T Urographic excretion study Dehydration and dose Aust Radiol 11 (1967) 261

BERKER F BOSTANCI N ALHAN M A OENER M and EFE F The effect of *furosemide* on water electrolytes titrable acid excretion osmolar clearance free water excretion urine pH and GFR in normal human subjects Istanbul Univ Tip Fak Med 29 (1966) 47?

BERKOVSKY I DRAJER [illegible] NIJENSOHN C M KOHAN A RAPAPORT S BERKOWSKI J PESCE R A and VALERO E M Mode of action of Furosemide in water diuresis V World Congr Cardiol New Delhi Part II (1966) 15

BJÖRK L *The osmotic effect of Urografin 76 per cent and Isopaque 60 per cent in angio* cardiography Amer J Roentgenol 98 (1966) 922

CATTELL W R FRY I K SPENCER A G and PURKISS P Excretion urography I Factors determining the excretion of Hypaque Brit J Radiol 40 (1967) 561

DACIE J E and FRY I K A comparison of sodium and methylglucamine diatrizoate in clinical urography Brit J Radiol 44 (1971) 51

DEILMANN W LAMPRECHT F ZIEGLER M und GROSS F Einfluss von *Furosemid auf die* Plasma reninaktivitat bei unilateral nephrectomierten Patienten Naunyn Schmiedberg s Arch exp Path Pharmak 270 (1971) Suppl No 22

DOYLE F H SHERWOOD T STEINER R E BRECKENRIDGE A and DOLLERY C T Large dose urography Is there an optimum dose? Lancet 2 (1967) 964

DURE SMITH P Drip infusion and routine urography A comparative trial Brit J Radiol 39 (1966) 655

attenuation of the renal pelvis (compared to that of non dehydrated animals) increased at both dose levels very much so at a dose of 320 mg I/kg body weight

Furosemide has mainly an effect on the proximal tubules and the loop of Henle by inhibiting the re absorption of sodium and water giving a high sodium excretion and diuresis (BERKOVSKY et coll 1966 RADO et coll 1969 GOTH 1972) Furosemide is also known to slightly increase the renal blood flow even in small doses (LUDENS et coll 1968 LUDENS & WILLIAMSON 1970) and to increase the glomerular filtration rate (BERKER et coll 1966, SZENDE et coll 1972) It also has a complex influence on the organism with a stimulating effect on the renin–angiotensin system and a secondary aldosterone secretion (ESPINER et coll 1969 IMBS et coll 1969 WERNZE 1970 DILLMANN et coll 1971) At present it is not known how these factors influence the urographic sequence The mechanism behind the effect noted in the present experiments appears to be due mainly to decreased volume of distribution of the contrast medium giving a higher blood iodine concentration and a remaining tubular effect by furosemide at the time of urography, which produces a higher contrast containing urine volume (Fig 5 0 5 mg furosemide and non dehydrated 160 and 320 mg I/kg b w) The increase in haematocrit values after furosemide dehydration indicates a decrease in plasma volume as also reported by others (ROSENTHAL et coll 1968) The extracellular space will also probably diminish somewhat after the heavy diuresis The amount of contrast medium excreted is determined by the filtered load i e the product of plasma iodine concentration and glomerular filtration rate (CATTELL et coll) At the time of urography (40 min after injection of furosemide) some tubular effect remained since diuresis usually reached base line values after 60 to 80 min After the higher doses of furosemide this effect caused a somewhat higher diuresis and larger volume of contrast containing urine The smaller dose of furosemide (0 25 mg) will probably have an effect similar to that of over night fluid restriction and a notable difference between the two situations cannot be expected The largest dose of furosemide (1 0 mg) is bound to have a more evident residual effect on the tubules giving a too high diuresis where the increase in urinary volume will counteract the increase in amount of iodine excreted resulting in a lower attenuation than after the medium dose (0 5 mg) of furosemide

Although some haemoconcentration was demonstrated in the present investigation after furosemide induced diuresis some decrease in haematocrit values can be expected following the injection of contrast medium especially so at high dose levels, due to the osmotic effect of the medium on the red blood cells (BJÖRK 1966 ASPELIN 1978) At the furosemide dose levels used in the present experiments the possibility of haemoconcentration in generally healthy patients should be nil Thus furosemide pre treatment might offer advantages over usual dehydration procedures in clinical practice either resulting in better attenuation due to increased urinary iodine concentration, or in reduction of the dose of contrast medium or both However further investigations in a clinical material will be needed to establish an optimum dose of furosemide on a per kg body weight basis

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BONE MINERAL CONTENT IN THE PROXIMAL TIBIA MEASURED BY COMPUTER TOMOGRAPHY

B LILIEQUIST S E LARSSON I SJOGREN G WICKMAN and K WING

Inspection of roentgen films is a poor method for estimating the bone mineral content as a 30 to 40 per cent change represents the threshold of detectability However bone mineral content is readily assessable using a variety of other methods all with various limitations Bone biopsy is a surgical procedure which permits the determination of the mineral content as well as the microscopic structure of the bone tissue However the method yields information from only a small region of the bone and most important it cannot be repeated for the measurement of the mineral content The most commonly used non invasive methods for measuring the mineral content include photon attenuation measurement with γ rays as originally described by CAMERON & SORENSEN (1967) with later modifications photodensitometry of roentgen films and for the estimation of the total bone mineral mass the neutron activation technique While the photon attenuation technique is accurate and reproducible it does not reveal the spatial distribution of mineral within the object The photodensitometry method will provide some information on the mineral distribution since an image of the bone is used but has a poor accuracy for in vivo measurements as the bone is surrounded by soft tissues Computer tomography has recently been introduced for bone mineral measurement by a number of authors RÜEGSEGGER et coll (1976) suggested the use of computer tomography with the radiation from a ^{125}I source LARSSON et coll (1978) discussed the potential use of dual energy scanning

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ESPINER E A JAGGER P I TUCCI J R and LAULER D P Effect of acute diuresis on aldosterone secretion in edematous patients New Engl J Med 280 (1969) 1141

FRY I K CATTELL W R SPENCER A G and PURKISS P Excretion urography II The relation between Hypaque excretion and the intravenous urogram Brit J Radiol 40 (1967) 572

GLANVILLE J N and HERLINGER H Normal hydration urography Clin Radiol 17 (1966) 230

GOTH A Medical pharmacology C V Mosby Co St Louis 1972

HARDT H Auswasch Urographie mittels Furosemid Vereinfachter Screening Test zur Diagnose der Nierenarterienstenose Fortschr Rontgenstr 118 (1973) 259

HARTLEY W Infusion urography Clin Radiol 17 (1966) 237

IMBS J L VELLY J SPACH A SCHREIBER A BLOCH R and SCHWARTZ J Control of renin release in the dog Proceedings of the Fourth International Congress of Nephrology p 140 Stockholm 1969

KEATES P G Improving the intravenous pyelogram An experimental study Brit J Urol 25 (1953) 366

LUDENS J H and WILLIAMSON H E Effect of Furosemide on renal blood flow in the conscious dog Proc Soc exp Biol 133 (1970) 513

— HOOK J B BRODY M J and WILLIAMSON H E Enhancement of renal blood flow by furosemide J Pharmacol exp Ther 163 (1968) 456

MCCLENNAN B L and BECKER J A Excretory urography Choice of contrast material—clinical Radiology 100 (1971) 591

MILES B E PATON A and DE WARDENER H E Maximum urine concentration Brit med J 2 (1954) 901

OWMAN T Excretion of sodium and methylglucamine diatrizoate after longtime unilateral ureteric stasis in the rabbit Acta radiol Diagnosis 20 (1979) 19

RADO J P SZENDE L TAKO J DANOS C and BORBELY L Further studies on the sites of action of Clopamide and Furosemide J clin Pharm 9 (1969) 99

ROSENTHAL J BOUCHER R NOWACZYNSKI W and GENEST J Acute changes in plasma volume renin activity and free aldosterone levels in healthy subjects following furosemide administration Canad J Physiol Pharmacol 46 (1968) 85

SCHENCKER B Drip infusion urography Radiology 83 (1964) 12

SHERWOOD T BRECKENRIDGE A DOLLERY C T DOYLE F H and STEINER R E (a) Intravenous urography and renal function Clin Radiol 19 (1968) 296

— DOYLE F H BRECKENRIDGE A DOLLERY C T and STEINER R E (b) Value of fluid deprivation in large dose urography Lancet 2 (1968) 754

SZENDE L RADO J and TAKO J Clinicopharmacological study of Profurit (furosemide) Thér Hung 4 (1972) 131

VAN WAES P F G M High dose urography in oliguric and anuric patients Excerpta Medica Amsterdam 1972

WERNZE H Zur diagnostischen Bedeutung von Renin Bestimmungen Med Welt 21 (1970) 921

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BONE MINERAL CONTENT IN THE PROXIMAL TIBIA MEASURED BY COMPUTER TOMOGRAPHY

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Inspection of roent en films is a poor method for estimating the bone mineral conte , as a 30 to 40 per cent change represents the threshold of detectability How ever bone mineral content is readily assessable using a variety of other methods all w h various limitations Bone biopsy is a surgical procedure which permits the deter mination of the mineral content as well as the microscopic structure of the bone tissue However the method yields information from only a small region of the bone and most important it cannot be repeated for the measurement of the mineral con te t The most commonly used non invasive methods for measuring the mineral con tent include photon attenuation measurement with γ rays as originally described by CAMERON & SORENSEN (1967) with later modifications photodensitometry of roentgen films and for the estimation of the total bone mineral mass the neutron activation technique While the photon attenuation technique is accurate and reproducible it does not reveal the spatial distribution of mineral within the object The photoden sitometry method will provide some information on the mineral distribution since an image of th bone is used but has a poor accuracy for in vivo measurements as the bone i surround d by soft tissues Computer tomography has recently been in troduced for bone mineral measurement by a number of authors RUEGSEGGER et coll (19/6) suggested the use of computer tomography with the radiation from a 125I source LARSSON et coll (1978) discussed the potential use of dual energy scanning

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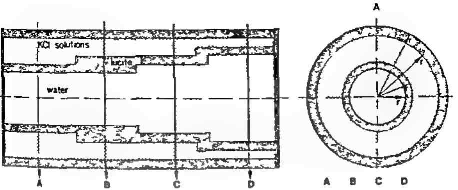
ESPINER E A JAGGER P I TUCCI J R and LAULER D P Effect of acute diuresis on aldosterone secretion in edematous patients New Engl J Med 280 (1969) 1141
FRY I K CATTELL W R SPENCER A G and PURKISS P Excretion urography II The relation between Hypaque excretion and the intravenous urogram Brit J Radiol 40 (1967) 572
GLANVILLE J N and HERLINGER H Normal hydration urography Clin Radiol 17 (1966) 230
GOTH A Medical pharmacology C V Mosby Co St Louis 1972
HARDT H Auswasch Urographie mittels Furosemid Vereinfachter Screening Test zur Diagnose der Nierenarterienstenose Fortschr Rontgenstr 118 (1973) 259
HARTLEY W Infusion urography Clin Radiol 17 (1966) 237
IMBS J L, VELLY J SPACH A SCHREIBER A BLOCH R and SCHWARTZ J Control of renin release in the dog Proceedings of the Fourth International Congress of Nephrology p 140 Stockholm 1969
KEATES P G Improving the intravenous pyelogram An experimental study Brit J Urol 25 (1953) 366
LUDENS J H and WILLIAMSON H E Effect of Furosemide on renal blood flow in the conscious dog Proc Soc exp Biol 133 (1970) 513
— HOOK J B BRODY M J and WILLIAMSON H E Enhancement of renal blood flow by furosemide J Pharmacol exp Ther 163 (1968) 456
McCLENNAN B L and BECKER J A Excretory urography Choice of contrast material—clinical Radiology 100 (1971) 591
MILES B E PATON A and DE WARDENER H E Maximum urine concentration Brit med J 2 (1954) 901
OWMAN T Excretion of sodium and methylglucamine diatrizoate after longtime unilateral ureteric stasis in the rabbit Acta radiol Diagnosis 20 (1979) 19
RADO J P SZENDE L TARO J DANOS C and BORBELY L Further studies on the sites of action of Clopamide and Furosemide J clin Pharm 9 (1969) 99
ROSENTHAL J BOUCHER R NOWACZYNSKI W and GENEST J Acute changes in plasma volume renin activity and free aldosterone levels in healthy subjects following furosemide administration Canad J Physiol Pharmacol 46 (1968) 85
SCHENCKER B Drip infusion urography Radiology 83 (1964) 12
SHERWOOD T BRECKENRIDGE A DOLLERY C T DOYLE F H and STEINER R E (a) Intravenous urography and renal function Clin Radiol 19 (1968) 296
— DOYLE F H BRECKENRIDGE A DOLLERY C T and STEINER R E (b) Value of fluid deprivation in large dose urography Lancet 2 (1968) 754
SZENDE L RADO J and TARO J Clinicopharmacological study of Profurét (furosemide) Thér Hung 4 (1972) 131
VAN WAES P F G M High dose urography in oliguric and anuric patients Excerpta Medica Amsterdam 1972
WERNZE H Zur diagnostischen Bedeutung von Renin Bestimmungen Med Welt 21 (1970) 921



	A	B	C	D
r	15	15	20	25
r	20	25	25	30
r	35	35	35	35
r	40	40	40	40 mm

Fig 2 Phantom designed to represent objects of similar sizes and linear attenuation coefficients as those assumed to exist in the proximal region of the tibia in adults The phantom was filled with solutions of KCl of various concentrations and known attenuation coefficients

measurements As a polychromatic beam passes through matter preferentially low energy photons are absorbed the beam hardens and the attenuation coefficient decreases with increased depth in the object Furthermore the relationship of the attenuation coefficients for bone and soft tissues varies with photon energy If no corrections are employed this effect leads to artefacts in the back projection varying with the size and composition of the object (BROOKS & DI CHIRO 1976) These effects are in part avoided in the scanner used in the present series through the waterbox and in part compensated for by software corrections (HOUNSFIELD 1977) It has been shown by RUTHERFORD et coll (1976) with a scanner of the same make and type as in the present series that the CT numbers are related in a linear way to the linear attenuation coefficients despite the polyenergetic character of the beam The phantom in Fig 2 was designed to represent objects of similar size and linear attenuation coefficients as those found in the proximal region of the tibia in adult patients In scans of this phantom the same linear relation between the calculated linear attenuation coefficient and the CT numbers was found as reported by RUTHERFORD et coll No significant difference was found between the various compartments in the phantom When the boundaries of the KCl solution were outlined and the mean HU was calculated in the same way as for the bone in the measurements made on patients the relationship of the average CT number to the KCl-concentrations up to 400 HU had a correlation coefficient of 0 999

Patient set up The prerequisites of the two applications of this method—the clinical diagnosis of bone disease and the evaluation of therapeutic measures—are different The reliability of the diagnostic method depends strongly on how accurately the

Fig 1 Modification of EMI scanner MKI for examination of proximal tibia Original water box substituted by a styrene copolymere block with a water filled cuff

using projection data obtained by radiation from [125]I and [241]Am while ISHERWOOD et coll (1976) REICH et coll (1976), GENANT & BOYD (1977) POSNER & GRIFFITHS (1977) and PULLAN & ROBERTS (1978) all advocated the use of commercially available head or body scanners employing roentgen radiation These reports discuss the potential use of the method but do not include clinical applications

The present report concerns the application of CT in the measurement of the distribution of bone of varying mineral content within a standardized cross section of the proximal tibia metaphysis and the possible use of this method in the clinical diagnosis and treatment of bone diseases

Method

An EMI scanner MKI was modified in order to provide cross sectional scanning facilities of the proximal tibia (WICKMAN et coll 1977) The modification involved substituting the original waterbox by a styrene copolymere block with a water filled cuff into which a longitudinally movable support and fixture for the leg had been fitted (Fig 1) With the patient s leg in the scanner aperture the proximal tibia is scanned at 120 kV producing a slice of 13 mm nominal thickness As a reference for scanner variations mainly involving the roentgen tube potential a curved sheet of lucite 2 cm thick fixed to the leg support is included in the scan

In the back projected CT number matrix the periphery of the tibia is outlined using a computer programme A cut off level of 80 Hounsfield units (HU) was chosen for the differentiation of bone from the surrounding soft tissues The average BMC within the outlined bone was defined as the sum of HU divided by the number of pixels within the outlined bone

Test for size and chemical composition dependency A fundamental difficulty with the present method is the use of a polychromatic photon beam for the transmission

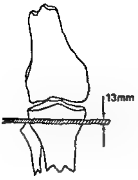


Fig 4 Anatomic orientation of the section used in the experiments

Discussion

In the present investigation a single roentgen beam quality was used The dual beam quality method as proposed by RUTHERFORD et coll , GENANT & BOYD and BROOKS & DI CHIRO allows the determination of the absolute bone mineral content even when unknown amounts of fat are present in the bone tissue However the dual beam quality method does not have as good measurement precision as the single quality method and for serial determinations in a given patient this precision is much more important than information as to the exact mineral content (GENANT & BOYD) Furthermore REICH et coll reported a very high correlation between calcium content and the average CT number for cadaver tibia and fibula specimens

A problem in bone mineral measurements is the correlation between changes in peripheral skeletal parts and the vertebral column Most often radiologic alterations of the vertebral column in the form of fractured vertebrae have been used as a criterion of osteoporosis Most metabolic bone diseases will affect the skeleton as a whole and therefore peripheral skeletal portions should be informative on general disease in bone metabolism

There is some evidence that bone mineral changes appear earlier in trabecular bone than in cortical bone possibly due to the more intimate connection with highly vascularized surrounding tissue Therefore changes in bone mineral content should be most easily detected in regions rich in trabecular bone In the proximal tibia a large volume of trabecular bone is located as well as cortical bone in sufficient amounts to allow the application of a mineral content determination method This region is also easily accessible for examination by the modified CT technique The leg is positioned in the machine in such a way that the distal of the two sections of a nominal 13 mm thickness will pass through the capitulum fibulae (Fig 4) The result can be immediately viewed at the display unit and a correction be made if necessary Usually 2 scanning sequences (4 sections) constitute one examination (Fig 5) Only one of the sections is chosen and further examined applying the method described and used in the original experiment

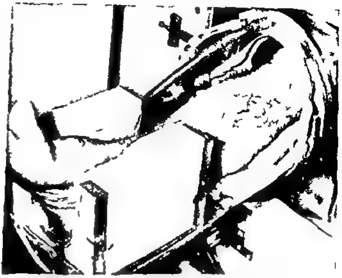
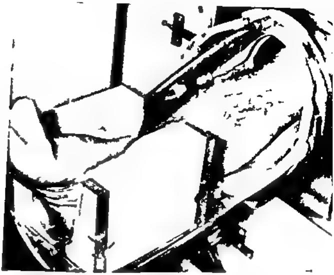


Fig 3 Individual leg support made of plaster of Paris assuring a reliable reposition of the leg

region to be examined can be located in each patient, and compared with the corresponding region in healthy individuals, reliable evaluation of therapy requires that the region first measured can be accurately relocated in succeeding scans even months apart The present method was designed mainly for evaluation of the changes in bone mineral content during therapy in patients with bone mineralization diseases The efforts were therefore concentrated on developing a method which would afford good reproducibility in repeated scans Palpation of the joint space proved to be unreliable as a reference for positioning of the section, as positioning errors of more than ± 1 mm often cause greater errors in the results than those caused by statistical and other variations inherent with the method

In order to determine the error of measurement under ideal conditions individual casts of plaster of Paris were made of the medial and lateral aspects of the ankles The casts were fixed with great precision to the leg support In repeat scanning the ankles and casts act as ball and socket joints fixing the tibia to the support in such a way as to make longitudinal and rotational movement very uncomfortable to the patient thus assuring a certain reliability in repositioning (Fig 3) The support with the leg and casts can be moved in or out of the aperture of the EMI scanner, and the exact longitudinal positioning relocated using a ruler fixed to the support giving the distance from the ankle fixture to the center of the scanned slice The positioning of an initial test scan for each patient was chosen at 95 per cent of the length of the tibia from the prominence of the medial malleolus to the palpated knee joint The anatomic information in the test scan was then used in selecting the position of a second section if necessary The distance on the ruler at this scan was noted for repositioning in repeat scanning

Reproducibility check Two volunteers were both scanned three times over a period of 13 days The reproducibility in the sum of HU and the mean HU within the bone region outlined had coefficients of variation of 1 6 and 2 1 per cent respectively



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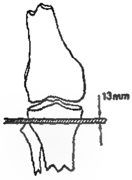

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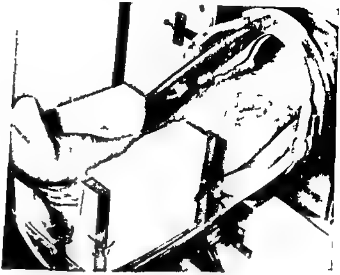

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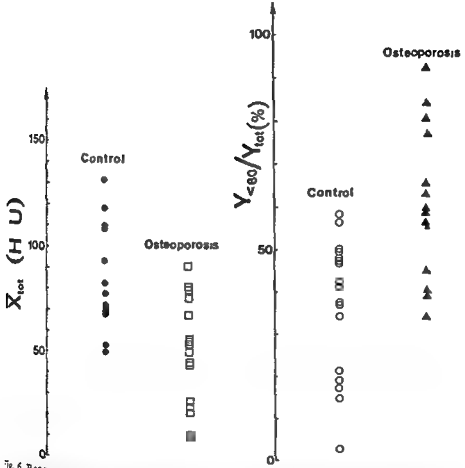

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A modified version of the EMI head scanner allows examination of the proximal ibia. By choosing appropriate display levels cortical bone can be differentiated from pongious bone and their relative volume as well as their mineral content can be stimated. Also the anatomic arrangement of the bone substance can be analysed. A difference in distribution of mineral content between the osteoporotic and the

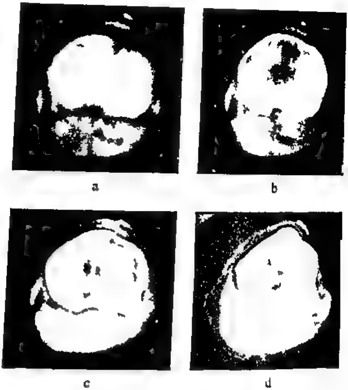

Fig. 5. Scans from a patient without mineral bone disease. Normal anatomic distribution of compact and trabecular bone.

Progressive bone demineralization is a part of a variety of diseases affecting the skeleton or the regulating mechanism for the calcium metabolism. Altered calcium metabolism appears in diseases involving vitamin D_3 metabolism; clinically they appear as different forms of osteomalacia, osteoporosis or more subtle changes in the bone mineralization. Recent investigations point to the great or decisive importance of the presence of DHCC metabolite for a normal calcium metabolism. Conventional radiologic examination can reveal osteoporosis only when about 30 per cent of the mineral content has disappeared. Changes due to osteomalacia are still more subtle and a definite discrimination between osteomalacia and osteoporosis is hitherto not achievable without a biopsy. However, this is a surgical procedure and cannot be repeated too often.

Some patients with known metabolic bone diseases were examined in order to illustrate differences in bone mineral content and its distribution. The findings are recorded as a diagram showing the relative amount of bone mineral of various mineral contents (Fig. 6) and also the anatomic distribution of those figures on the scans (Fig. 7). Of interest is the difference in distribution of bone with high mineral content in a patient with osteoporosis and one with osteomalacia. In the patient with osteoporosis the high mineral content is concentrated in the compact bone while the mineral has disappeared in the trabecular bone; no figures indicating any bone mineral content are present centrally (Fig. 8). This is not the case in the patient with osteomalacia where large amounts of bone with low mineral content are found

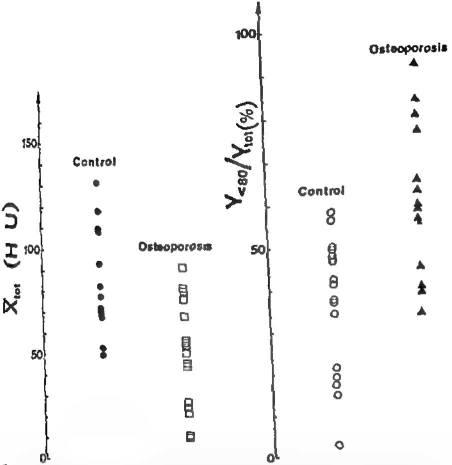

Fig. 6 Bone measurements in patients with and without osteoporosis. Total sum of HU in relation to the total surface area examined in patients with and without osteoporosis (left). Relative surface of bone containing HU above 80 related to the total surface area examined in the two groups (right)

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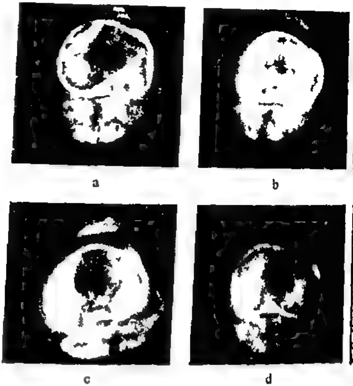

Fig 7 Distribution of high mineral bone content (HU > 220) in 2 patients with osteoporosis (a b) and in 2 patients with osteomalacia (c d)

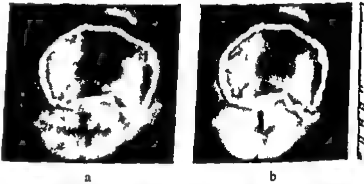

Fig 8 Osteoporosis Preponderance of high mineral bone content in the region of compact bone a) HU > 220 b) HU > 120

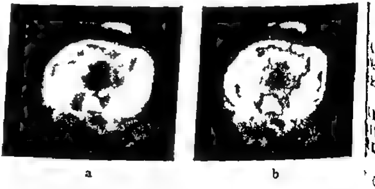

Fig 9 Osteomalacia Low mineral bone content in the region of trabecular bone a) HU > 220 b) HU > 120

osteomalacic bone is evident The method is very sensitive and small differences can be recorded, if the reproducibility is adequate Reproducibility has been experimentally demonstrated to be acceptable it is better than with other methods such as

photon absorption or neutron activation techniques as the correct anatomic section can be analysed during the examination and a correction be made if necessary The effect of therapeutic regimens as the highly effective vitamin D_3 metabolite 1 25 DHCC can probably be monitored

SUMMARY

With a slight modification of the EMI MK1 scanner a sensitive method for examination of the bone mineral content in the proximal tibia was achieved The method allows an estimation of the amount of trabecular and cortical bone as well as their mineral content The anatomic structure of the bone substance is demonstrated differing in osteoporosis and osteomalacia The reproducibility is acceptable

ZUSAMMENFASSUNG

Mit einer leichten Modifikation des EMI MK1 Scanners wurde eine empfindliche Methode fur die Untersuchung des Knochen Mineralgehalts in der proximalen Tibia erreicht Die Methode erlaubt eine Bestimmung der Menge des trabekularen und kortikalen Knochens sowie dessen Mineralgehalts Es wird gezeigt dass die anatomische Struktur der Knochen substanz unterschiedlich bei Osteoporose und Osteomalacie ist Die Reproduzierbarkeit ist hinreichend

RÉSUME

Une legere modification du scanner EMI MK1 a permis de mettre au point une methode sensible d examen de la teneur minérale de l os dans la partie proximale du tibia Cette methode permet une estimation de la quantité d os trabeculaire et d os cortical ainsi que de leur teneur minerale La structure anatomique de la substance osseuse est mise en evidence differente dans l ostéoporose et dans l osteomalacie La reproductibilite est acceptable

REFERENCES

BROOKS R A and DI CHIRO G Beam hardening in X ray reconstructive tomography *Phys in Med Biol* 21 (1976) 390

— — Split detector computed tomography A preliminary report Radiology 126 (1978) 255

CAMERON J R and SORENSEN J A A reliable in vivo measurement of bone mineral content J Bone Jt Surg 49 A (1967) 481

GENANT H K and BOYD D Quantitative bone mineral analysis using dual energy computed tomography Invest Radiol 12 (1977) 545

HOUNSFIELD G N Physical measurements of the EMI imaging system *In* Reconstruction tomography in *diagnostic radiology and nuclear medicine* p 217 Edited by M M Ter Pogossian J R Cox M E Phelps D D Davis G L Brownell and R G Evens University Park Press Baltimore London Tokyo 1977

ISHERWOOD I RUTHERFORD R A PULLAN B R and ADAMS P H Bone mineral estimation by computer assisted transverse axial tomography Lancet II (1976) 712

LARSSON S BERGSTROM M DAHLQVIST I ISRAELSSON A and LAGERGREN C A method for determining bone mineral content using Fourier image reconstruction and dual source technique J Comp Ass Tomogr 2 (1978) 347

POSNER I and GRIFFITHS H J Comparison of CT scanning with photon absorptiometric measurement of bone mineral content in the appendicular skeleton Invest Radiol 12 (1977) 542

PULLAN B R and ROBERTS T B Bone mineral measurements using an EMI scanner and standard methods A comparative study Brit J Radiol 51 (1978) 24

REICH N E SEIDELMANN F E TUBBS R R MACINTYRE W J MEANY T F ALFIDI R J and PEPE R G Determination of bone mineral content using CT scanning Amer J Roentgenol 127 (1976) 593

RUTHERFORD R A PULLAN B R and ISHERWOOD I Measurement of effective atomic number and electron density using an EMI scanner Neuroradiology 11 (1976) 15

RUEGSEGGER P ELSASSER U ANLIKER M GNEHM H KIND H and PRADER A Quantification of bone mineralization using computed tomography Radiology 121 (1976) 93

WICKMAN G LILIEQUIST B and JOHANSSON R A substitute for the water box in the original EMI brain scanner J Comp Ass Tomogr 1 (1977) 333

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RADIOGRAPHY IN JOINT RECONSTRUCTION WITH PERICHONDRIAL GRAFTS

H WILBRAND and O ENGKVIST

The surgical treatment of degenerative joint disease in the hand still constitutes a difficult clinical problem Generally accepted methods such as arthrodesis or arthroplasty of the excisional or interpositional type often give good results but have special indications and certain drawbacks A more physiologic surgical approach is desirable especially in young patients The cartilage forming capacity of the perichondrium which has been recognized for more than a hundred years (ARCHANGELSKY 1868 GENZMER 1876 SALTYKOW 1900 HAAS 1914 LOEB 1926 FELL 1932) has recently been demonstrated in a series of experiments by SKOOG et coll (1972) and OHLSÉN (1976) This capacity of the perichondrium appears to offer a good possibility in this new approach to the surgical treatment of degenerative joint disease

In rabbits perichondrium from the ear or the rib has been shown to give rise to cartilage which both macro and microscopically resembles normal articular cartilage when grafted to a surgically created defect of the joint surface (ENGKVIST & WILANDER 1979) or to a joint surface from which all the ordinary cartilage has been removed (ENGKVIST & OHLSÉN 1979) Rib perichondrium from adult dogs proved to have the same chondrogenic potential when autologously grafted to the joint surface of the patella from which all normal cartilage had been removed down to subchondral bone (ENGKVIST 1979)

The good results of these animal experiments have motivated the use of the method in clinical practice The purpose of the present investigation was to determine

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whether joints reconstructed with free autologous perichondrial grafts in which the clinical results were considered excellent presented any specific radiographic features The value of arthrography in evaluating the appearance of the reconstructed joint space was also assessed

Material and Methods

ENGKVIST & JOHANSSON (1979) reported on the results of perichondrial arthroplasty of the small joints of the hand or foot in 26 patients followed up from 3 to 40 months The present radiographic investigation comprised 13 of these patients, in whom the clinical results were considered excellent with improvement of power and the range of movement and freedom from pain The indication for operation was pain or stiffness in the affected joint In 6 of the 13 patients reconstructive surgery was carried out in the metacarpophalangeal joint, among these, the indication for surgery was discomfort caused by post infectious arthritis in 2 cases post traumatic degeneration in one case and rheumatoid arthritis in 3 In 3 patients the proximal interphalangeal joint was grafted 2 of these patients had an idiopathic degenerative joint disease and one a post traumatic arthritis Perichondrial arthroplasty with an excellent result was also performed in one carpometacarpal joint of the thumb because of idiopathic degenerative arthritis and in 2 metatarsophalangeal joints of the big toe because of post traumatic and congenital abnormalities One patient underwent reconstruction of the elbow joint with perichondrial grafting because of post infectious arthritis

General operative procedure After opening the affected joint the degenerated cartilage was removed down to bleeding subchondral bone care being taken to maintain the essential shape of the joint surfaces Perichondrium from the cartilaginous part of one of the lower ribs was then grafted to the joint surfaces and attached to the bone or the marginal soft tissues by sutures in such a way that the resected surfaces were completely covered by the grafts The side of the perichondrium that originally adhered to the rib cartilage was turned to face the joint space A thin Silastic sheet was interposed in the joint to prevent the 2 grafts from growing together After closure the joint was immobilized for 3 to 4 weeks before the commencement of physiotherapy The removal of the Silastic sheet 12 to 16 weeks after grafting gave an opportunity to inspect the joint surfaces At the same time in some cases a small biopsy was taken from the newly formed tissue on the resected joint surfaces Microscopy demonstrated cartilage with a hyaline appearance and a distinct but irregular borderline between the bone tissue and the newly formed cartilage (Fig 1)

Pre and postoperative radiography was carried out with a tube with a focal size of 0 3 mm and a photographic system consisting of a film screen combination of

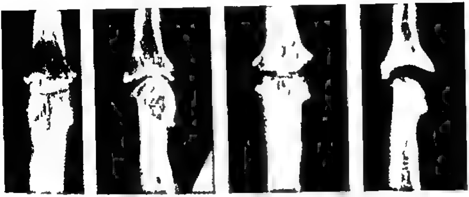
Fig. 1 Light microscopy of newly formed cartilage on the humeral articular surface of the elbow joint in a 39 year-old man 4 months after perichondrial grafting The cartilage covering the bone has a fairly mature appearance with closely situated cells resembling chondrocytes basally and smaller more separated cells towards the surface Presence of proteglycans characteristic of normal cartilage in the intercellular substance stained with saffranin O The border between the bone and the cartilage is distinct but somewhat irregular depending on the distribution and shape of the trabeculae of the spongy bone (saffranin O 80)

either X omatic Regular Screens and X omatic G film or high definition screens MR 50 (Agfa Gevaert) and Medichrome film (Agfa Gevaert)

Postoperative radiography was performed after 1 to 3 months and subsequently at varying intervals up to a maximum of 40 months after the operation depending on the individual clinical requirements The minimum follow up period was 13 months

In 3 cases the final examination of 2 metacarpophalangeal joints and one proximal interphalangeal joint was completed with arthrography of the restored joint under local anaesthesia After fine needle puncture of the joint from the dorsal aspect under fluoroscopy about 0 5 ml of meglumine amidotrizoate containing 0 65 g I/ml (Angiografin Schering) were instilled The amount of injected contrast medium varied with the filling capacity of the reconstructed joint space

Fig 2 Metacarpophalangeal joint of the long finger reconstructed with perichondrial grafts in a 20 year old man with a painful post infectious arthritis after a saw accident giving an open joint wound a b) Preoperative film of the affected joint c) 4 months after reconstructive surgery d) 18 months after surgery slightly irregular cortical de marcation e) 40 months after reconstruction the cortical bone demarcation is fairly distinct and somewhat irregular f) At arthrography 40 months after surgery the joint space has almost the same appearance as the corresponding joint space in a healthy individual (Fig 5) Accidental lymphatic drainage



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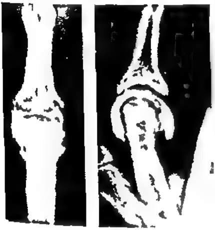

e f

Fig 3 Proximal interphalangeal joint of the ring finger reconstructed with perichondrial grafts in a 52 year old cleaner with an idiopathic degenerative arthritis with rather severe pain a b) Preoperative appearance c d) 13 months after surgery Cortical bone demarcation is fairly well developed and irregular e f) Arthrography 23 months after surgery The joint space displays a more regular outline than the cortical bone demarcation The size of the joint space corresponds well with the range of movement of the joint and differs somewhat from that in the control (Fig 6)

In view of the sparsity of reports on arthrography of finger joints it seemed necessary to perform similar examinations of healthy joints for comparison with the findings in the reconstructed joints These were performed on the authors

Results

At radiography of the reconstructed joints during the first 3 months postoperatively no obvious alterations were observed in the bony contour close to the joint space other than slight demineralization of the bone However 8 to 11 months postoperatively a distinct tendency to cortical bone demarcation was apparent close to the newly formed cartilaginous outlining of the joint without any alteration of the previous contour This demarcation of the bone cortex became more marked 11 to

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Fig 5 Arthrography of a healthy proximal interphalangeal joint a b) Semiflexed position of the joint large proximal volar and dorsal pouch of the joint slightly extended by contrast medium. c) In volar flexion contrast medium is expelled to th proximal volar pouch of the joint d) In extreme extension most of the contrast medium is collected in the proximal dorsal pouch and a small amount left in the proximal volar pouch

extent of the joint resembled that of the controls but with certain differences The articular surface appeared even though the cortical bone contours were somewhat irregular

Discussion

The radiographic findings during the first 3 months postoperatively corresponded well with the microscopic appearance as shown in Fig 1 the trabeculae of the cancellous bone at the borderline between the bone and the newly formed cartilage had an uneven distribution and shape Unfortunately biopsies from humans are not available from any later period of time after grafting However experiments in dogs have shown that after several months the trabecular component of the spongy bone just beneath the cartilage has increased and the borderline is more even (ENGKVIST) At radiography this should be reflected as a cortical demarcation of the bone structures as was in fact observed on the films of the present material obtained 8 months after surgery and later

The radiographic appearance of distinct cortical bone demarcation against the reconstructed cartilage of the joint 8 to 11 months postoperatively was in full

Fig 4 Proximal interphalangeal joint of the ring finger reconstructed with perichondrial grafts in a 65 year old housewife with idiopathic degenerative disease giving a limited range of movement and disabling pain during household duties a) Preoperative appearance of the joint b c) 4 months after surgery no evident cortical bone demarcation Interposed Silastic sheet d e) 10 months after surgery irregular cortical bone demarcation fairly well developed f g) 19 months after operation Cortical bone demarcation well developed

16 months after surgery Further examinations only confirmed the consolidation of the demarcation process (Figs 2 3 4)

Arthrography of the normal proximal interphalangeal joint in the healthy individuals revealed that the joint space extended proximally for a relatively long distance (Fig 5) On flexion of the joint the contrast medium was collected in an extended proximal volar pouch of the joint space whereas on extreme extension most of it was expelled to a proximal dorsal pouch a minor amount being retained in the volar pouch

Arthrography of the normal metacarpophalangeal joint (Fig 6) revealed that the joint also had a large dorsal extension but with smaller recesses in its volar aspect In the reconstructed joints the joint space readily filled with contrast medium The

similar volar pouch This recess is of great importance to the mobility of the joint and its obliteration is considered to be a reason for some of the failures after perichondral arthroplasty (ENGKVIST & JOHANSSON) Arthrography is the best method of determining whether or not such a volar pouch is present

The observation at arthrography of the normal proximal interphalangeal joint that the contrast medium was expelled to different areas in flexion and extreme extension of the joint indicate that dorsal puncture of this joint should be performed with the finger in semiflexion under fluoroscopy

SUMMARY

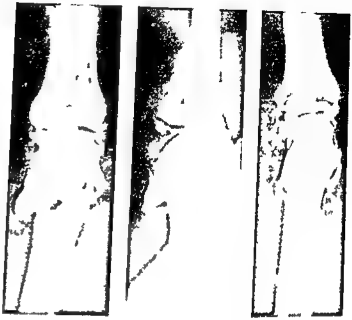
The radiographic findings in 13 joints successfully reconstructed with free perichondrial grafts from the rib are reported Radiography was performed during a period of 13 to 40 months postoperatively Definite cortical demarcation occurred after 8 to 11 months and had increased 11 to 16 months following surgery In 3 cases the final examination of 2 metacarpophalangeal joints and one proximal interphalangeal joint was completed with arthrography which demonstrated that the articular surfaces appeared even although the cortical bone contours were somewhat irregular The extent of the joint spaces largely resembled that in healthy controls

ZUSAMMENFASSUNG

Die radiographischen Befunde an 13 Gelenken werden berichtet welche mit freier Verpflanzung von Rippenperichondrium mit Erfolg rekonstruiert wurden Die Rontgenuntersuchungen wurden 13 bis 40 Monate lang nach der Operation ausgefuhrt Kortikale Demarkation wurde nach 8 bis 11 Monaten sichtbar und verdeutlichte sich 11 bis 16 Monate nach der Operation Zur Vervollstandigung der abschliessenden Untersuchung wurden zwei Metacarpophalangealgelenke und ein proximales Interphalangealgelenk mit Arthrographie untersucht In den Arthrographien zeigten die Gelenkoberflachen ein ebenmassiges Aussehen obwohl die kortikalen Knochenkonturen etwas uneben waren Das Ausmass des Gelenkspaltes entsprach im Grossen und Ganzen dem der gesunden Kontrollen

RESUME

Les auteurs presentent les aspects radiographiques dans 13 articulations reconstruites avec succes au moyen de greffe perichondrale libre prise sur une cote La radiographie a ete faite au cours d une periode allant de 13 à 40 mois aprés l operation Une demarcation corticale nette apparait entre 8 à 11 mois et augmente de 11 a 16 mois après l intervention Dans 3 cas l examen final de 2 articulations métacarpophalangiennes et d une articulation interphalangienne proximale a eté complete par arthrographie qui a montre que les surfaces articulaires sont regulieres meme quand le contour de l os cortical est un peu irregulier La largeur de l espace interarticulaire est dans l ensemble comparable a celui des sujets temoins sains



a b c

Fig 6 Arthrography of a healthy metacarpophalangeal joint a b) Extension c) Semiflexion

correspondence with the gradually regained function as also was the subsequent consolidation Thus the appearance of the cortical bone demarcation without alteration of the primary postoperative bone contour is one radiographic indication of a successful surgical reconstruction of the joint even though the zone of demarcation may appear somewhat irregular A restored joint space at arthrography is another favourable finding

It would be of value to have early radiographic information which would be of prognostic aid Due to the small number of cases and the random distribution of the radiography over the period of 3 to 8 months following surgery no analysis was possible in this respect A radiographic comparison between this limited number of 13 clinically successful cases and 9 failures from the same series reported by ENGKVIST & JOHANSSON gave no further information of prognostic value additional to that mentioned Since the number of patients operated upon with perichondrial arthroplasty is increasing earlier and more detailed comparative observations may facilitate the recognition of early indication of prognostic value

Arthrography of the small joints of the extremities is not regarded as a routine procedure It is sometimes indicated in extreme extensibility of the joints combined with painful lesions and in cases of doubt as to whether periarticular calcifications are related to the joint or the joint capsule (HAAGE 1973) On the other hand arthrography of reconstructed finger joints is of greater informational value

HAAGE (1966) described the delicate joint space in the finger joints with its bursa like dorsal proximal pouch and pointed out that for puncture a fine needle should be used Arthrography of the normal proximal interphalangeal and metacarpophalangeal joints in the present investigation, performed with this technique, also revealed a

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REFERENCES

ARCHANGELSKY Ueber die Regeneration des hyalinen Knorpels Zentralbl Med Wissensch 6 (1868) 658

ENGKVIST O Reconstruction of patellar articular cartilage with free autologous perichondrial grafts An experimental study in dogs To be published in Scand J plast reconstr Surg (1979)

— JOHANSSON S H Perichondrial arthroplasty A clinical study in 26 patients To be published in Scand J plast reconstr Surg (1979)

— OHLSÉN L Reconstruction of articular cartilage with free autologous perichondrial grafts An experimental study in rabbits To be published in Scand J plast reconstr Surg (1979)

— WILANDER E Formation of cartilage from rib perichondrium grafted to an articular defect in the femoral condyle of the rabbit To be published in Scand J plast reconstr Surg (1979)

FELL H B Chondrogenesis in cultures of endosteum Proc roy Soc 112 (1932) 417

GENZMER A Ueber die Reaktion des hyalinen Knorpels auf Entzundungsreize und die Vernarbung von Knorpelwunden nebst einigen Bemerkungen zur Histologie des Hyalin Knorpels Virchows Arch (Pathol Anat) 67 (1876) 75

HAAGE H Methodik und Indikationen zur Arthrographie Med Welt 17 (1966) 1313

— Arthrographie der kleinen Hand und Fingergelenke *In* Handbuch der medizinischen Radiologie Band V/2 p 399 Springer Berlin Heidelberg New York 1973

HAAS S L Regeneration of cartilage and bone with a special study of these procedures as they occur at the chondrocostal junction Surg Gynec Obstet 19 (1914) 604

LOEB L Autotransplantation and homotransplantation of cartilage in the guinea pig Amer J Pathol 2 (1926) 111

OHLSÉN L Cartilage regeneration from perichondrium Experimental studies in rabbits and dogs Abstracts No 252 Uppsala Dissertations from the Faculty of Medicine 1976

SALTYKOW S Ueber Transplantation zusammengesetzter Teile Arch Entw Org 9 (1900) 329

SKOOG T OHLSÉN L and SOHN [redacted] A Perichondrial potential for cartilaginous regeneration Scand J plast reconstr Surg 6 (1972) 123

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CHOICE OF SCREENS IN HIGH SPEED ANGIOGRAPHY

S REICHMANN K ÅSTRAND and L LUNDIN

High sensitivity of the recording medium has been one major solution for reducing patient exposure It is well known that such increased speed involves a risk of decreased image quality Attempts to explain this circumstance have mainly been focused on the loss of sharpness which is inevitable in high speed intensifying screens This loss of sharpness may be mathematically expressed by means of the modulation transfer function (MTF MORGAN et coll 1964) Thus the MTF has mainly been used for the evaluation of screen performance However another form of image deterioration in high speed radiography is the quantum mottle By definition this mottle consists of background density fluctuations due to the statistical distribution of a limited number of roentgen photons giving rise to the image These density fluctuations may cover small image details to the point where these cannot be identified The influence of this relative lack of photons which is further augmented with increased screen speed is not confined to the background fluctuations alone (REICHMANN & ÅSTRAND 1979) Therefore the relationship between decreased exposure and image information capacity is still incompletely known

The sensitivity of a screen film combination may be influenced by changing the film speed This in turn may be achieved by means of different modes of development The MTF is then kept constant and so the influence of the relative lack of photons may be visually evaluated However this technique has certain limits since film development deviating too much from what is recommended may lead to impaired film performance Previously (REICHMANN et coll 1978) the Agfa Gevaert Medichrome colour film was found to make possible speed variations amounting to a

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Table

Survey of the screens tested containing either lanthanum oxybromide (LOB) or barium fluorochloride (BFC) The total processing time in minutes at 37 C for the Medichrome film is indicated yielding desired film density for the two levels of exposure used These levels correspond to par speed × 2 (4 0 mAs) and par speed × 3 (2 5 mAs)

Screen name	Phosphor	Processing time	
		2 5 mAs	4 0 mAs
Agfa Gevaert MR 600	LOB	3 0	2 5
Siemens Titan	LOB	3 0	2 5
Ilford Rapide	LOB	3 5	3 0
Agfa Gevaert MR 400	LOB	3 5	3 0
Test screen	BFC	4 5	3 5
Philips Massiot Azuray II	BFC	4 5	3 5
Agfa Gevaert MR 200	LOB	—	5 3

factor of 2 5 to 3 without impaired information capacity in fact this capacity was clearly superior to that of a standard black and white film (Agfa Gevaert Curix RP 1) In experiments now reported a phantom with vessels of small calibre was exposed using various high speed screens differing in sensitivity by a factor of 3 constant photographic density of the final films being obtained by means of different modes of development The influence of screen unsharpness could then be analysed without the final image being simultaneously affected by any significant difference in quantum mottle

Experiments

The blood vessel phantom was obtained from an autopsy specimen of pancreas containing barium sulphate as contrast medium The soft tissues were removed Radiography was performed at 60 kV using an additional tube filtration of 0 8 mm Cu and 1 mm Fe The vessel phantom was surrounded by air The geometric conditions eliminated any significant influence of focus unsharpness A number of different screens were used as listed in the Table in conjunction with Agfa Gevaert Medichrome film All films were processed in a Pakorol machine at a temperature of 37°C The different processing times are listed in the Table indicating relative differences in speed between different screens Two phosphor substances were tested viz lanthanum oxybromide and barium fluorochloride In the latter case one screen was commercially available (Philips Massiot Azuray II) the other being a test screen made by another manufacturer These two substances may be expected to attenuate the radiation in a similar way with regard to the spectral distribution of the radiation since lanthanum and barium differ only little in atomic number

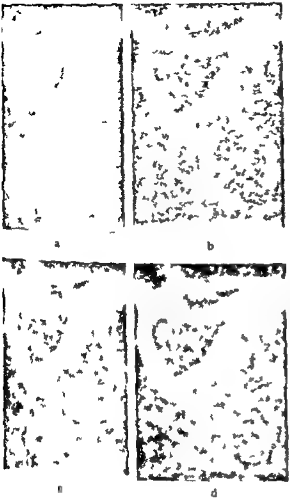
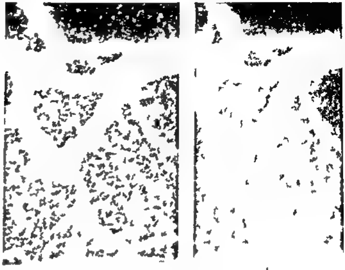


Fig. 1 Films (magnified 3) of a vessel phantom In a) a Siemens Titan screen was used In b) a Philips-Massiot Azuray II screen was given the same exposure the difference in screen speed being eliminated by more intense development thus causing greater contrast besides greater sharpness However the same object details appear in both films When the images are converted to identical contrast and sharpness (c and d respectively) it becomes still more evident that the information content of the two films is identical since the conversion did not entail any reduction of the number of visible details in (b) despite increased unsharpness

Two series of films were obtained at different mAs settings of the generator as listed in the Table The films produced differed greatly in sharpness contrast and visible background fluctuations However the evaluation of the image quality was concentrated on the sole question of how many details pertaining to the object could be identified in the image Thus a film displaying more object details was considered preferable regardless of contrast sharpness and visual impression of background fluctuations In order to increase the reliability of inspection all films were photographed onto a fine grain panchromatic emulsion (Agfapan 25) by means of orange light The negatives formed were of the same size as the original Under constant increase of contrast these negatives were magnified 4 times onto film (Agfa Gevaert N 41 p) The magnification and increase of contrast made inspection considerably easier above all as regards comparison between different films



a b

Fig. 2. Three films superimposed. In a) the films were copies of the same original superimposition leading merely to increased contrast but not to increased information. When copies of three different originals were superimposed (b) the resulting image corresponded to a threefold increase of radiographic exposure: obvious increase of information.

On the whole, no significant difference was noted as to the number of visible details as long as the exposure was kept constant. Thus, screens giving rise to low unsharpness were not superior to those of high unsharpness. Furthermore, screens of low unsharpness giving rise to a low output of light made it necessary for the development of the films to be increased. Therefore, in the films obtained, low unsharpness and high contrast tended to occur simultaneously. However, neither of these factors appeared to be of significance as compared with the exposure. The difference between the two series of different exposure was not great enough to be presented in an illustration, the difference being seen mainly in the form of a scattered dropout of minor details in the lower exposure series.

Even though contrast and unsharpness did not mean variations in the amount of visible details, they certainly affected the visual appearance of the films (Fig. 1 a, b). The greatest difference in this respect was seen between the Titan screen and the Azuray II. An aftertreatment of these two images obtained with 4 mAs exposure was carried out in order to demonstrate that the same image would be obtained if contrast and unsharpness were brought to the same level. The following technique was used. The negatives obtained when the original films were photographed were magnified onto N 41 p film. By means of different development the two secondary films were brought to the same contrast. The films were rephotographed onto Agfa pan 25. The Titan image which displayed lower sharpness was photographed with the camera lens adjusted to maximum sharpness. The Azuray II image, on the other hand, was rephotographed in a series with increased defocusing of the lens, giving rise to increased unsharpness. Thus, a negative could be selected, displaying the same visual degree of unsharpness as did the Titan image. In this way the Azuray II film displaying higher sharpness and contrast in the original (Fig. 1 a, b), could be given the same visual appearance as the Titan image (Fig. 1 c, d) without loss of object

information This observation lends further support to the assumption that under the radiographic conditions of the experiments unsharpness of the screens and contrast of the film were merely of secondary importance as compared with the radiographic exposure

Another form of aftertreatment was also carried out The different magnified films could be superimposed and still be inspected in strong light This could even be done with three films without density being troublesome When magnified films obtained from different originals were used new details always appeared in the image despite their being invisible in each of the magnified films when inspected separately (Fig 2) This was not due to a simple increase of contrast since superimposition of several magnified films deriving from the same original did not give rise to increased information Likewise unsharpness of the screens seemed to be of no significance since the same details tended to appear in the image when films from unsharp screens were superimposed as observed when films from sharper screens were used The superimposition in itself implied increased radiographic exposure Thus this observation points in the same direction as those described indicating that exposure is of predominating importance under the experimental conditions as compared with screen unsharpness and film contrast

Discussion

The present investigation constitutes a test of a series of modern intensifying screens of moderate or high sensitivity with regard to capacity for depiction of very small blood vessels The actual amount of information obtained under the prevailing test conditions was chiefly determined by the radiographic exposure Contrary to what might be expected screen unsharpness and film contrast as controlled by different modes of development did not visibly affect the number of object details appearing in the image However since the test conditions to a certain degree deviate from the conditions present in the clinical situation the difference between the test situation and the clinical examination such as abdominal angiography have to be considered

The exposure level used in the present experiments implied a fairly moderate screen film speed amounting to par speed $\times 2$ and par speed $\times 3$ respectively The latter speed is often employed in clinical angiography However the introduction of new high speed screens is likely to bring higher screen film sensitivities into common use Thus the test series was performed at a rather high level of radiographic exposure to the intensifying screens as compared with everyday angiography Further more the conditions of attenuation in the object probably implied higher contrast of the radiation relief than in clinical radiography of corresponding small blood vessels since the radiation was rather soft and the blood vessels were contrasted against air rather than soft tissues No secondary radiation was present The higher the contrast of the radiation relief and the larger the number of the photons giving

rise to the final image the more likely it is that unsharpness will limit the information capacity of the image. Since the present experiment was carried out with a higher number of photons and a higher contrast of the radiation relief than usually is encountered in clinical radiography, there appears to be no reason to expect screen unsharpness to be of greater importance in the clinical situation than it was in the test.

It may be expected that the screens tested would display somewhat different degrees of attenuation, leading to variations in the actual radiographic exposure. However, this factor did not visibly affect the final image quality.

In the phantom experiments the only important factor giving rise to image unsharpness was inherent in the intensifying screens and the cross over exposure of the film. The phantom itself lay so close to the recording medium that no focus unsharpness should be expected, and since a phantom was used, motion unsharpness was eliminated. In clinical examinations additional unsharpness due to these two factors is usually encountered. However, this does not invalidate the conclusion that radiographic exposure is more important than screen unsharpness, since if unsharpness deriving from other sources is added to that from the screens, the differences between various screens will at most be reduced or eliminated.

Previously (REICHMANN & STRID 1979) the influence of secondary radiation was tested under conditions similar to those in the present experiment. Above all, it was investigated to what degree removal of a smaller or larger fraction of secondary radiation could be compensated for by means of increased screen film speed. Improved secondary screening means reduced exposure, first, by the removal of the secondary radiation itself, and secondly, by stealing part of the primary radiation otherwise reaching the recording medium. It was demonstrated that increased secondary screening was an efficient means of improving image quality. In order to avoid an increased radiation dose to the patient a shift to higher screen film speed was found recommendable. The increased unsharpness thus introduced did not appear to affect image quality adversely, an observation which is explained by the present experiments. The fact that the radiographic exposure has been found to be the predominant factor determining image quality in angiography in fact implies that the signal/noise ratio limits information capacity much more than does unsharpness. Increased secondary screening yields a more favourable signal/noise ratio and, apparently, improved image quality may thus be achieved even at the cost of somewhat increased screen unsharpness and, to a certain degree, reduced radiographic exposure to the screens.

SUMMARY

In phantom experiments a number of intensifying screens were tested as regards their usefulness for angiography. Film speed was adjusted so as to make possible a constant radiographic exposure despite screen speeds varying by a factor of 3. Thus, screen unsharpness varied considerably. However, it was of no practical importance as long as the

radiographic exposure was kept constant This observation indicates that the modulation transfer function is of limited value in differentiating between screens for high speed angiography Likewise film contrast was of little significance for image quality as compared with radiographic exposure to the intensifying screens

ZUSAMMENFASSUNG

Bei Phantomexperimenten wurden eine Anzahl von Verstarkerschirmen hinsichtlich der Anwendbarkeit fur die Angiographie gepruft Die Schirmgeschwindigkeit wurde dahingehend justiert dass es moglich wurde eine konstante Rontgenexposition zu halten obwohl die Geschwindigkeiten der Schirme um einen Faktor 3 variierten Somit veranderte sich die Schirmunscharfe wesentlich Das war jedoch nicht von praktischer Bedeutung, solange die Rontgenexposition konstant gehalten wurde Diese Beobachtung deutet darauf hin dass die Modulationstransferfunktion von begrenztem Wert ist bei der Differenzierung zwischen Schirmen fur die hoch Geschwindigkeitsangiographie Ebenso war der Filmkontrast von geringer Bedeutung fur die Bildqualitat verglichen mit der Rontgenexposition der Verstarkerschirme

RÉSUME

Un certain nombre d ecrans renforçateurs ont eté testés au cours d experiences sur fantome en ce qui concerne leur utilite pour l angiographie La rapidite du film a ete ajustee de façon a permettre une exposition radiographique constante malgre des rapidites d ecrans renforçateurs allant de un à trois Dans ces conditions le flou d ecran a varie considérablement Cependant il n avait pas d importance pratique dans la mesure ou l exposition radiographique était maintenue constante Cette observation montre que la fonction de transfert de modulation a un interet limite pour établir une difference entre les écrans renforçateurs utilises pour l angiographie a grande vitesse De meme le contraste du film a peu d importance pour la qualite d image en comparaison de l exposition radiographique des ecrans renforçateurs

REFERENCES

MORGAN R H BATES L M GOPALARAO U V and MARINARO A The frequency response characteristics of X ray films and screens Amer J Roentgenol 92 (1964) 426

REICHMANN S and STRID K G Diagnostically acceptable level of secondary radiation Acta radiol Diagnosis 20 (1979) 145

— and ÅSTRAND K Influence of radiation dose on image quality Acta radiol Diagnosis 20 (1979) 393

— HELANDER C G and SELIN K Medichrome film as an alternative to silver free recording systems Acta radiol Diagnosis 19 (1978) 513

Book review

ESSENTIALS OF RADIOLOGY FOR MEDICAL STUDENTS AND OTHERS WHO FIND LOOKING AT RADIOGRAPHS VERY DIFFICULT 178 pages By P M Bretland Butterworths London and Boston 1978

The author states in the preface that he has no intention to compete with any of the recognized textbooks of radiology The purpose of the book as well as the group of prospective readers it is aimed at appear clearly from the sub title The material is divided into four chapters with the following titles Chest Abdomen Bones and Skull respectively Joints are included under the heading Bones Other subjects are also treated shortly Very little is said about the technique of examination The booklet is certainly useful to read for non radiologists seeking a short introduction into the art of evaluating conventional roentgen films i e films obtained without the use of contrast medium of any kind The text is fluent and easy to follow with emphasis laid on matters of practical importance It is a pity that many of the numerous illustrations are of such poor quality that an evaluation of details is impossible

Alfred S amosi

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DIAGNOSIS

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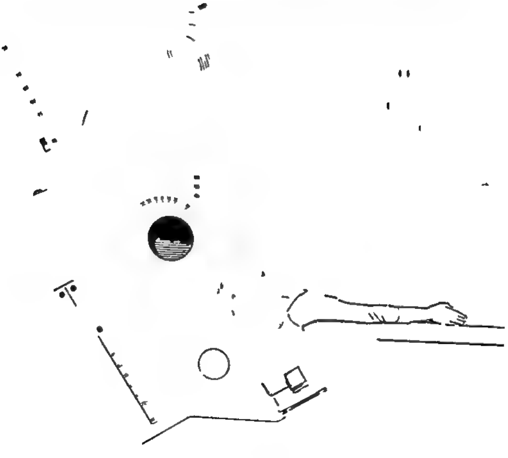

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